ACR No. 4B28

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

February 1944 as

Advance Confidential Report 4B28

WIND-TUNNEL INVESTIGATION OF CONTROL-SURFACE CHARACTERISTICS

XVIII - A LINKED OVERHANG AERODYNAMIC BALANCE

By Richard I. Sears and Robert B. Liddell

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NACA

WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE CONFIDENTIAL REPORT

WIND-TUNNEL INVESTIGATION OF CONTROL-SURFACE CHARACTERISTICS

XVIII - A LINKED OVERHANG AERODYNAMIC BALANCE

By Richard I. Sears and Robert B. Liddell

SUMMARY

Wind-tunnel tests have been made in two-dimensional flow to investigate the aerodynamic characteristics of a flap balanced by a large overhang linked to deflect more slowly than the flap. Three lengths of blunt-nose overhang were tested linked to a 0.30-airfoil-chord straight-contour flap on an NACA 66-009 airfoil.

The test results indicated that the linked overhang was capable of producing as highly balanced flap hinge moments as can be obtained with other types of aerodynamic balance. At the same time, the linked-balance flap produced slightly higher lift at large deflections than the corresponding unbalanced or internally balanced flap and much higher lift than flaps balanced by smaller conventional type overhangs. Such characteristics can be obtained with a linked balance because much balance can be obtained without the nose of the overhang protruding sufficiently far into the air stream to cause severe air-flow separation at large deflections.

Because the hinge-moment parameters are functions of the rate of balance deflection, adjustment of the balancing characteristics of a control surface can be made on each individual airplane merely by changing the length of a link.

INTRODUCTION

Attempts to produce a highly balanced control surface by providing a flap with a large overhang or internal balance usually impair the maximum lift that would be produced by the surface without the balance. Flaps with large overhangs generally encounter air-flow separation at large deflections, and flaps with large internal balances usually cannot be deflected to large angles because of space limitation.

One possible means of obtaining the lift of an unbalanced plain flap with the hinge moments of a balanced surface was suggested in reference 1, which proposed that a control surface overbalanced by a large overhang be provided with a tab to deflect in the same direction and as some function of the control-surface deflection. By this means, the control surface might be limited to low deflections free from air-flow separation yet the lift would be increased by the tab deflection. This arrangement was tested on a finite-span model of a horizontal tail surface (figs. 127 to 130 of reference 2) in the LMAL 7- by 10-foot tunnel. The tab deflection, however, increased the hinge moments of the control surface so rapidly that the desired increments of lift caused by tab deflection could not be achieved without excessively large hinge moments.

The tab characteristics presented in figure 147 of reference 2 indicate the optimum length of tab to use to increase the lift of an overbalanced control surface restricted in deflection range. An analysis of these data and the data of figure 141 of reference 2 leads to the conclusion that a tab with a chord equal to the chord of the control surface should provide a maximum increment in lift for a minimum increment in hinge moment. Such an arrangement is the equivalent of deflecting the portion of the movable surface ahead of the hinge axis at a slower rate than the portion behind the hinge axis.

The desirability of linking an overhang balance to deflect at a different rate from that of the control surface to be balanced having been established, the problem arises of the optimum length overhang and rate of deflection. Because the unporting angle and the resulting separation over the nose of the balance vary roughly as the first power of the balance length whereas the balancing moment varies as some power of the balance length higher than the square, it should be aerodynamically advantageous to increase the balance length and to make the balance deflect more slowly. Such a procedure must, however, be limited by structural and practical considerations.

The current series of tests were therefore made to determine the extent to which the lift characteristics of an unbalanced control surface could be maintained while the control surface was provided with as great a degree of aerodynamic balance as is commonly obtained on control surfaces highly balanced by conventional means.

SYMBOLS

The coefficients and the symbols used in this paper are defined as follows:

c_l airfoil section lift coefficient (l/qc)

c_{d_o} airfoil section profile-drag coefficient (d_o/qc)

c_m airfoil section pitching-moment coefficient (m/qc^2)

c_h flap section hinge-moment coefficient (h/qc_f^2)

where

l airfoil section lift

d_o airfoil section profile drag

m airfoil section pitching moment about quarter-chord point of airfoil

h flap section hinge moment

c chord of basic airfoil with flap and tab neutral

c_f flap chord (measured from hinge axis to trailing edge)

q dynamic pressure

and

c_b balance chord (measured from hinge axis to nose of balance)

α_o angle of attack for airfoil of infinite aspect ratio

δ_f flap deflection with respect to airfoil

δ_b balance deflection with respect to airfoil

$$c_{l_\alpha} = \left(\frac{\partial c_l}{\partial \alpha_o}\right)_{\delta_f}$$

$$\alpha_\delta = \left(\frac{\partial \alpha_o}{\partial \delta_f}\right)_{c_l}$$

$$c_{h_\alpha} = \left(\frac{\partial c_h}{\partial \alpha_o}\right)_{\delta_f}$$

$$c_{h_\delta} = \left(\frac{\partial c_h}{\partial \delta_f}\right)_{\alpha_o}$$

$$\left(c_{m_{c_l}}\right)_\delta = \left(\frac{\partial c_m}{\partial c_l}\right)_{\delta_f}$$

$$\left(c_{m_{c_l}}\right)_\alpha = \left(\frac{\partial c_m}{\partial c_l}\right)_{\alpha_o}$$

The term "conventional overhang," used in this paper for comparison with the linked overhang, refers to the inset-hinge type of aerodynamic balance.

APPARATUS, MODEL, AND TESTS

The tests were made in the NACA 4- by 6-foot vertical tunnel (reference 3) modified as discussed in reference 1. The 2-foot-chord by 4-foot-span model was made of laminated mahogany to the NACA 66-009 airfoil contour forward of the hinge axis and to a straight-line contour behind the hinge axis. The model was provided with a flap having a chord 30 percent of the airfoil chord and with three interchangeable blunt-nose overhang balances having chords 50, 75, and 100 percent of the flap chord (fig. 1). The flap and the overhang balance had a common hinge axis. The overhang balance was deflected as a function of the flap deflection by means of a linkage system (fig. 2).

The balance deflection and the rate of balance deflection (mechanical advantage of the balance over the flap) can be obtained analytically for any given flap deflection. If x and y are as indicated in figure 2,

$$\tan \delta_b = \frac{\sin \delta_f}{\frac{x}{y} + \cos \delta_f} \tag{1}$$

and

$$\frac{d\delta_b}{d\delta_f} = \frac{\left(1 + \frac{x}{y}\cos\,\delta_f\right)\cos^2\delta_b}{\left(\frac{x}{y} + \cos\,\delta_f\right)^2} \qquad (2)$$

The departure of balance deflection and rate of balance deflection from linearity with flap deflection, as calculated by equations (1) and (2), was small and is indicated in figure 3 for each linkage arrangment tested. The actual deflections of the balances on the model were measured within $\pm 0.1^\circ$ of the calculated values. In order to obtain the values of $d\delta_b/d\delta_f$ that were tested on the model, x and y were varied with interchangeable links.

The airfoil model when mounted in the tunnel completely spanned the test section. With this type of installation, two-dimensional flow is approximated and section characteristics of the model can be determined. The balance arrangements tested and the test conditions are given in table I. The gap referred to in table I and throughout this paper is the gap at the nose of the balance. The gap at the hinge axis (between the flap and the balance) was sealed with sheet rubber for all tests.

The flap with the $0.75c_f$ overhang was tested with balance neutral ($d\delta_b/d\delta_f = 0$) in order to simulate a plain flap. For a few tests of the plain flap, the gap at the nose of the neutral $0.75c_f$ overhang was filled with plasticine to give a smooth airfoil contour except for a break at the hinge axis.

It is estimated that the angle of attack of the airfoil was set within $\pm 0.10^\circ$ and that the flap deflection was set within $\pm 0.20^\circ$.

An experimentally determined tunnel correction was applied to the lift. The angle of attack and hinge moments were corrected for the effect of streamline curvature induced by the tunnel walls in accordance with a theoretically derived analysis similar to that presented in reference 4 for finite-span models. Values of drag are subject to an undetermined tunnel and turbulence correction.

The tunnel-wall corrections were applied in the following manner:

$$c_l = \left(0.965 - 0.007\ \left|c_{l_T}\right|\right) c_{l_T}$$

$$\alpha_o = \alpha_{o_T} + \left(0.21c_{l_T} - 0.134c_{l_{T_f}}\right)$$

$$c_h = c_{h_T} + 0.070c_{l_T}F$$

where

α_{o_T} tunnel angle of attack

c_{l_T} tunnel lift coefficient

$c_{l_{T_f}}$ tunnel lift coefficient caused by flap deflection (taken arbitrarily at $\alpha_{o_T} = -8^\circ$)

c_{h_T} tunnel hinge-moment coefficient

and F is a constant which is a function of each balance arrangement and is given in the following table:

$d\delta_b/d\delta_f$ \ c_b/c_f	0.50	0.75	1.00
0.17	----------	----------	--~~0.072~~--
.21	----------	0.073	----------
.25	----------	----------	.059
.33	----------	.065	----------
.39	----------	.065	----------
.50	0.076	.048	----------
.56	.076	----------	----------
.75	.065	----------	----------
1.00	.054	-.002	-.060

DISCUSSION

Lift

The lift characteristics of the plain flap (see figs. 4 and 15), simulated by causing the $0.75c_f$ overhang

L-350

to remain neutral when the flap was deflected, may be used as a basis for judging the effect of the various linked balances on the lift curves. As shown by figure 4, the lift and hinge-moment characteristics of the simulated plain flap changed very little when the gap at the nose of the sealed $0.75c_f$ overhang was filled to form an airfoil of true contour ahead of the hinge axis. The lift curves for the plain flap are typical of the lift curves for low-drag airfoil sections (references 5 and 6).

Figures 4 to 22 indicate that the linked balance affected the lift and hinge-moment characteristics in the manner anticipated. Increments of lift caused by flap deflections less than 10° were nearly the same for all lengths of overhang tested regardless of rate of balance deflection. The $1.00c_f$ overhang with $d\delta_b/d\delta_f = 1.00$ did, however, give a slightly greater increment of lift at $\delta_f \ngtr 10^{\circ}$ than the plain flap. At $\delta_f \nless 10^{\circ}$, therefore, little air-flow separation presumably occurred over the upper surface of the flap or balance for any arrangement of balance tested.

At $\delta_f > 10^{\circ}$, the increments of lift produced by flap deflection were greatly affected by the length and rate of deflection of the balance. For each length of balance, the lift characteristics at large deflections improved as the rate of balance deflection with flap deflection was decreased from $d\delta_b/d\delta_f = 1.00$. With the $0.75c_f$ and $1.00c_f$ linked balances, for low values of $d\delta_b/d\delta_f$, the lift obtainable throughout the angle-of-attack range for flap deflections greater than 10° was equal to and often greater than with the plain flap. With the $0.50c_f$ linked balance, however, the lift obtainable for flap deflections greater than 10° was generally not quite so great as that produced by the plain flap.

Unsealing the gap at the nose of the balance was found to have an adverse effect on lift characteristics of the flaps with large overhangs (figs. 15 to 22 and table I).

The data presented in figure 23 for the three linked balances, the conventional $0.50c_f$ overhang balance ($d\delta_b/d\delta_f = 1.00$), and the plain flap are for a straight-contour flap and were obtained from the present investigation. The data for the conventional $0.35c_f$ overhang balance were for a cusped flap and were obtained from reference 5. These data clearly indicate that a flap with a linked balance is capable of producing much higher lift than a flap highly balanced by a conventional overhang and slightly higher lift than an unbalanced plain flap.

It is to be expected that a 0.30c flap with internal balance capable of giving hinge-moment characteristics comparable with those of the linked balances of figure 24 could not be deflected more than $\pm 20^\circ$ because of space limitation in the balance chamber. The lift characteristics of such an internally balanced flap would therefore be expected to be the same as for the sealed plain flap limited to $\pm 20^\circ$ deflection.

Hinge Moment

The hinge-moment curves for the plain flap (fig. 4) are typical of those for low-drag airfoil sections (references 5 and 6). The rapid change in hinge-moment coefficient with angle of attack at angles of attack near the airfoil stall was typical of all balance arrangements tested. The plain and balanced flaps previously tested on the NACA 66-009 airfoil (figs. 97 to 106 of reference 2) had hinge-moment curves similarly affected by air-flow separation.

In the present tests, with gap unsealed, most of the hinge-moment curves with the $0.75c_f$ and $1.00c_f$ overhangs became undesirably nonlinear with change in angle of attack. The change due to gap in the variation of hinge-moment with flap deflection was not so great.

With some linked-balance arrangements including that with the overhang balance rigidly attached to the flap in order that $d\delta_b/d\delta_f = 1.00$ and also with the unbalanced plain flap, a violent oscillation of the flap occurred at certain angles of attack at large flap deflections. All ranges in which this oscillation of the flap existed are noted by dashed lines in the hinge-moment curves of figures 4 to 22. The flaps with the linked-balance arrangements that gave closely balanced hinge moments were entirely free from oscillation. A linked balance thus provides one means of eliminating these flap oscillations.

It is believed that oscillations of the flap could occur with many conventional blunt-nose overhangs. These oscillations have not been evident on models previously tested in the NACA 4- by 6-foot vertical tunnel because the flaps have been restrained in deflection by a stiff strain gage; the flap of the present model was restrained, however, by only a limber torque rod. Similar oscillations have been noticed on ailerons tested in the LMAL 7- by 10-foot tunnel (reference 7).

The hinge-moment characteristics of flaps with two of the linked balances tested are compared in figure 24 on the basis of lift with those of a cusped flap having a conventional $0.35c_f$ overhang (reference 5). A flap with conventional overhang greater than $0.35c_f$ might have given, at low deflections, hinge moments more nearly equivalent to those of the linked balance but the lift at large deflections would be less than that for the $0.35c_f$ overhang. It does not seem probable, therefore, that the variation of hinge-moment coefficient with lift coefficient for the linked-balance flap as shown in figure 24 can be reproduced by conventional types of aerodynamic balance on a 0.30c flap.

The hinge-moment parameters c_{h_α} and c_{h_δ} for the various arrangements of linked balance tested were measured at $\alpha_0 = \delta_f = 0^\circ$ from the curves of figures 4 to 22 and plotted in figure 25 as functions of rate of balance deflection $d\delta_b/d\delta_f$. The large positive increment in c_{h_α} with gap is clearly evident in figure 25. For the $0.75c_f$ balance, unsealing the gap did not change c_{h_δ}.

Drag

At $\alpha_0 = \delta_f = 0^\circ$, the minimum profile-drag coefficient with the break in airfoil contour at the nose of the sealed $0.75c_f$ overhang was found to be 0.0010 greater than with the break filled with plasticine to form an airfoil of smooth contour. This increment in drag coefficient, caused by the addition of the $0.75c_f$ overhang on a 0.30c flap, was the same as the increment caused by the addition of a $0.35c_f$ blunt-nose overhang to a 0.26c flap on the same airfoil. The latter increment was measured on the control-surface arrangement shown in figure 103 of reference 2, although the drag results are unpublished.

The increments of airfoil section profile-drag coefficient at $\alpha_o = 0^\circ$ caused by deflection of the flap with various arrangements of linked balance and of the unbalanced plain flap are shown in figure 26. The data show that, for rates of balance deflection which give nearly similar hinge-moment characteristics, the increment of drag at a given flap deflection tends to decrease as the overhang increases.

The drag data indicate that, by increasing the length of a flap overhang and causing it to deflect at a slower rate than the flap in order to maintain nearly equivalent highly balanced hinge moments, the air-flow separation can be delayed. This phenomenon is especially apparent at large flap deflections.

The variation in profile-drag coefficient with angle of attack is about the same for all three balance lengths, whether the gap at the nose of the balance is sealed or unsealed. The unsealed balances have somewhat greater drag, however, than the sealed balances at angles of attack between 0° and $\pm 6^\circ$ but have about the same drag at an angle of attack of 0° and at angles of attack greater than $\pm 6^\circ$.

Pitching Moment

Pitching-moment characteristics, which are considered of secondary importance, have been presented in figures 4 to 22 only for those arrangements of linked balance for which the hinge moments were reasonably small. A complete list of values of $c_{m_{c_l}}$ is given, however, in table I. These values are indicative of the locations of the centers of lift caused by angle of attack and by flap deflection.

Practical Considerations

The data presented indicate that the linked balance is an aerodynamically desirable type of control-surface balance. The magnitudes of the peak pressures at the nose of the balance, however, have not yet been investigated. It is expected that the peak pressures would be smaller than for a flap with a conventional blunt-nose overhang giving similar hinge-moment characteristics because the linked overhang moves a relatively small distance and never protrudes far into the air stream. For any deflections of the linked balance, the peak pressures at the flap hinge axis should tend to be smaller than with a plain flap.

L-350

Of the three overhangs tested, the $0.75c_f$ overhang appears to have an optimum length from combined aerodynamic and structural considerations. Although it is better to have the nose of the overhang sealed, it is believed that small leaks will less critically affect the hinge moments than with an internal balance. In order to minimize twist, the linked balance may be connected to the flap at several spanwise stations in order that the balancing moment will be distributed along the span of the flap in a manner approximating that of a conventional rigidly attached overhang. The mass moment of the linked overhang will tend to mass-balance the flap.

One advantage of the linked balance is that the overall hinge-moment characteristics can be easily changed because the parameters c_{h_α} and c_{h_δ} are functions of $d\delta_b/d\delta_f$, as shown by figure 25. Mechanisms can be devised that would vary the rate of balance deflection in one or more of the spanwise balance sections by changing the length of a link or a pivot location, either on the ground or in flight. Adjustments can thus easily be made to correct undesirable hinge-moment characteristics caused by surface irregularities or changes in contour.

CONCLUSIONS

The results of tests of an NACA 66-009 airfoil with a 0.30-airfoil-chord straight-contour flap having various arrangements of overhang balance linked to deflect more slowly than the flap indicated the following conclusions:

1. A flap with linked balance was capable of producing as highly balanced hinge moments as a flap with other types of aerodynamic balance. At the same time, the linked-balance flap was capable of producing slightly higher lift than an unbalanced or internally balanced flap of equal chord and much higher lift than a flap of equal chord balanced by a conventional overhang.

2. The lift and drag data indicated that increasing the length of the flap overhang and causing it to deflect more slowly to maintain nearly equivalent highly balanced hinge moments tended to delay air-flow separation over the flap and balance, especially at large flap deflections. The increase in minimum drag caused by a large linked overhang was the same as that caused by a small blunt-nose overhang of conventional type.

3. Both the lift and the hinge-moment characteristics of a control surface with large overhang balance were adversely affected by the presence of a gap at the nose of the balance.

4. The hinge-moment characteristics of a control surface with a linked overhang could easily be adjusted either in flight or on the ground by changing the length of a link or a pivot location in the linkage system of one or more spanwise sections of the overhang balance.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

L-350

REFERENCES

1. Sears, Richard I., and Hoggard, H. Page, Jr.: Wind-Tunnel Investigation of Control-Surface Characteristics. II - A Large Aerodynamic Balance of Various Nose Shapes with a 30-Percent-Chord Flap on an NACA 0009 Airfoil. NACA A.R.R., Aug. 1941.

2. Sears, Richard I.: Wind-Tunnel Data on the Aerodynamic Characteristics of Airplane Control Surfaces. NACA ACR No. 3L08, Dec. 1943.

3. Wenzinger, Carl J., and Harris, Thomas A.: The Vertical Wind Tunnel of the National Advisory Committee for Aeronautics. Rep. No. 387, NACA, 1931.

4. Swanson, Robert S., and Toll, Thomas A.: Jet-Boundary Corrections for Reflection-Plane Models in Rectangular Wind Tunnels. NACA ARR No. 3E22, May 1943.

5. Gillis, Clarence L., and Lockwood, Vernard E.: Wind-Tunnel Investigation of Control-Surface Characteristics. XIII - Various Flap Overhangs Used with a 30-Percent-Chord Flap on an NACA 66-009 Airfoil. NACA ACR No. 3G20, July 1943.

6. Purser, Paul E., and Riebe, John M.: Wind-Tunnel Investigation of Control-Surface Characteristics. XV - Various Contour Modifications of a 0.30-Airfoil-Chord Plain Flap on an NACA 66(215)-014 Airfoil. NACA ACR No. 3L20, Dec. 1943.

7. Rogallo, F. M., and Purser, Paul E.: Wind-Tunnel Investigation of 20-Percent-Chord Plain and Frise Ailerons on an NACA 23012 Airfoil. NACA A.R.R., Dec. 1941.

TABLE I

INFORMATION CONCERNING ARRANGEMENTS OF LINKED BALANCES TESTED

$\frac{c_b}{c_f}$	$\frac{d\delta_b}{d\delta_f}$	Gap	Reynolds number	c_{l_α}	α_δ	c_{h_α}	c_{h_δ}	$\left(c_{m_{c_l}}\right)_\delta$	$\left(c_{m_{c_l}}\right)_\alpha$	Figure
0.75	0.00	Sealed	2.4×10^6	0.097	-0.57	-0.0053	-0.0100	0.000	-0.168	4
.50	.56	--do--	2.4	.098	-.58	-.0018	-.0040	.007	-.196	5
.50	1.00	--do--	2.4	.096	-.60	.0006	.0046	.000	-.200	6
.75	.21	--do--	2.4	.095	-.58	-.0020	-.0062	.007	-.185	7
.75	.33	--do--	2.4	.097	-.58	.0000	-.0027	.007	-.179	8
.75	.39	--do--	2.4	.095	-.60	.0009	-.0010	.009	-.179	9
.75	.50	--do--	2.4	.096	-.60	.0028	.0032	.000	-.189	10
.75	1.00	--do--	2.4	.098	-.66	.0062	.0260	.000	-.168	11
1.00	.17	--do--	2.4	.097	-.55	.0000	-.0044	.000	-.182	12
1.00	.25	--do--	2.4	.095	-.58	.0028	.0000	.000	-.189	13
1.00	1.00	--do--	1.6	.097	-.63	.0310	.0660	.000	-.197	14
.75	.00	0.005c	2.4	.063	-.55	-.0048	-.0100	-.008	-.213	15
.50	.50	.005c	2.4	.079	-.63	.0002	-.0035	.000	-.225	16
.50	.75	.005c	2.4	.080	-.70	.0022	.0000	.005	-.193	17
.50	1.00	.005c	2.4	.072	-.74	.0078	.0040	.000	-.194	18
.75	.39	.005c	2.4	.064	-.62	.0093	-.0010	-.010	-.206	19
.75	.50	.005c	2.4	.068	-.60	.0115	.0030	-.012	-.188	20
.75	1.00	.005c	2.4	.070	-.72	.028	.027	-.017	-.147	21
1.00	1.00	.005c	1.6	.083	-.78	.050	.056	-.030	-.145	22

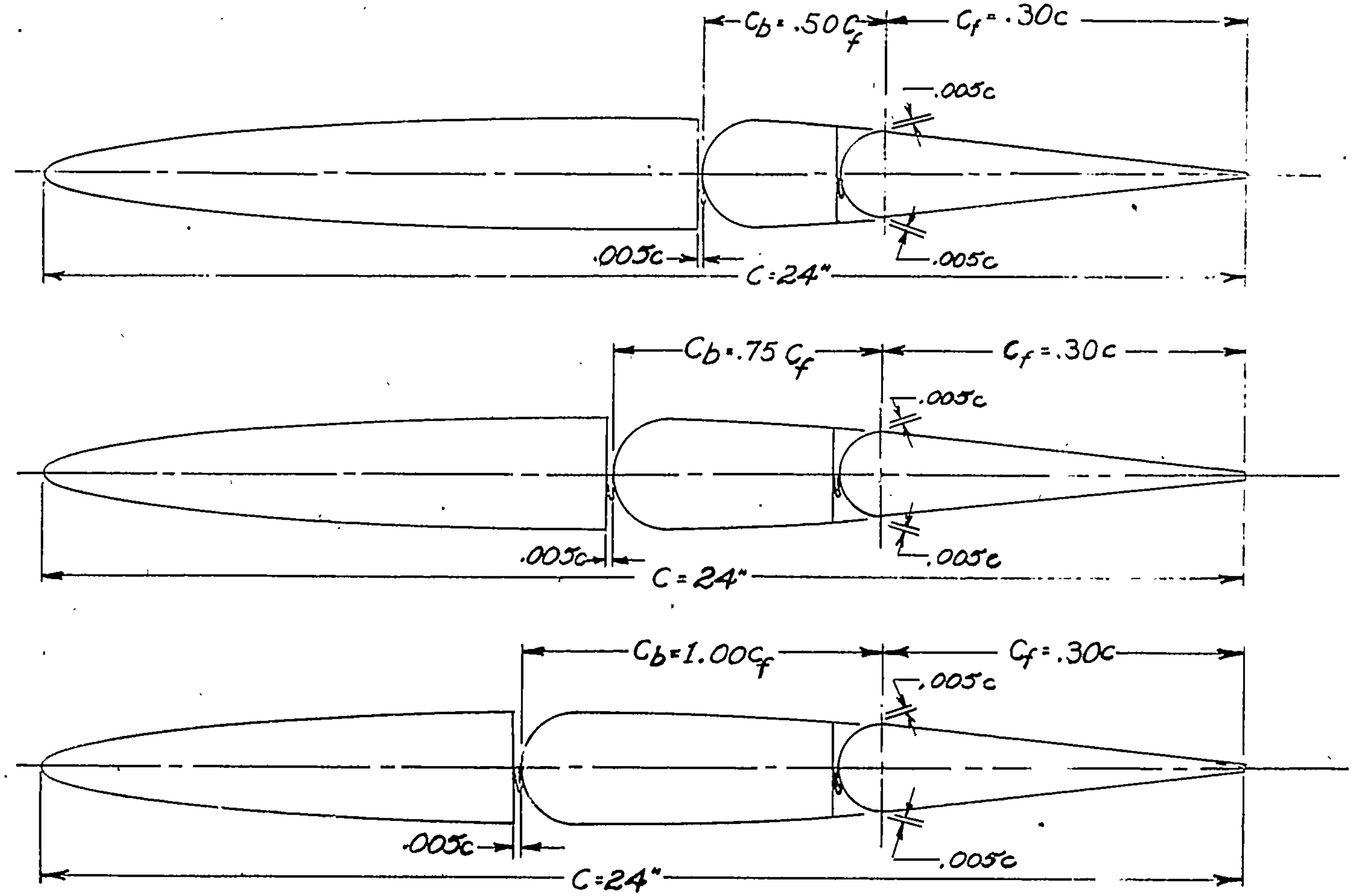


Figure 1.- Arrangements of linked balance tested on an NACA 66-009 airfoil with a 0.30c straight-contour flap.

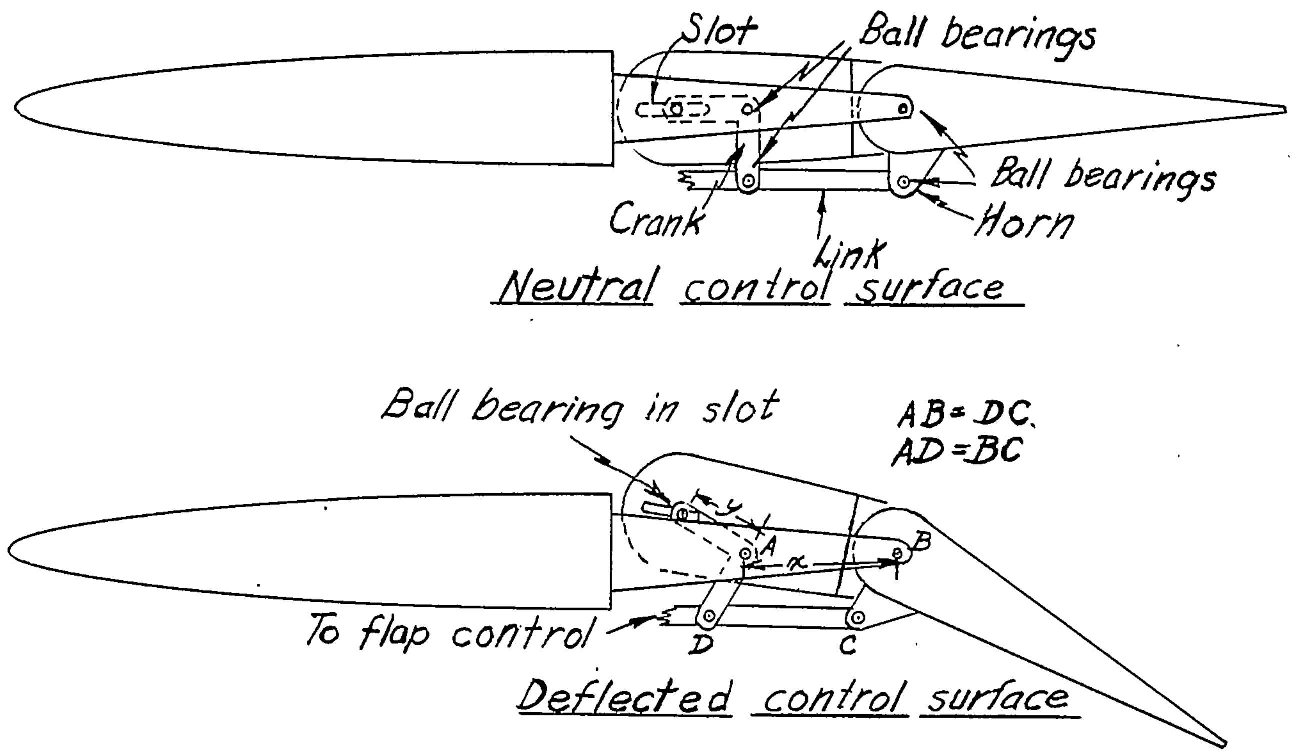


Figure 2.- Schematic diagrams of linkage system used to deflect linked balance.

L-350

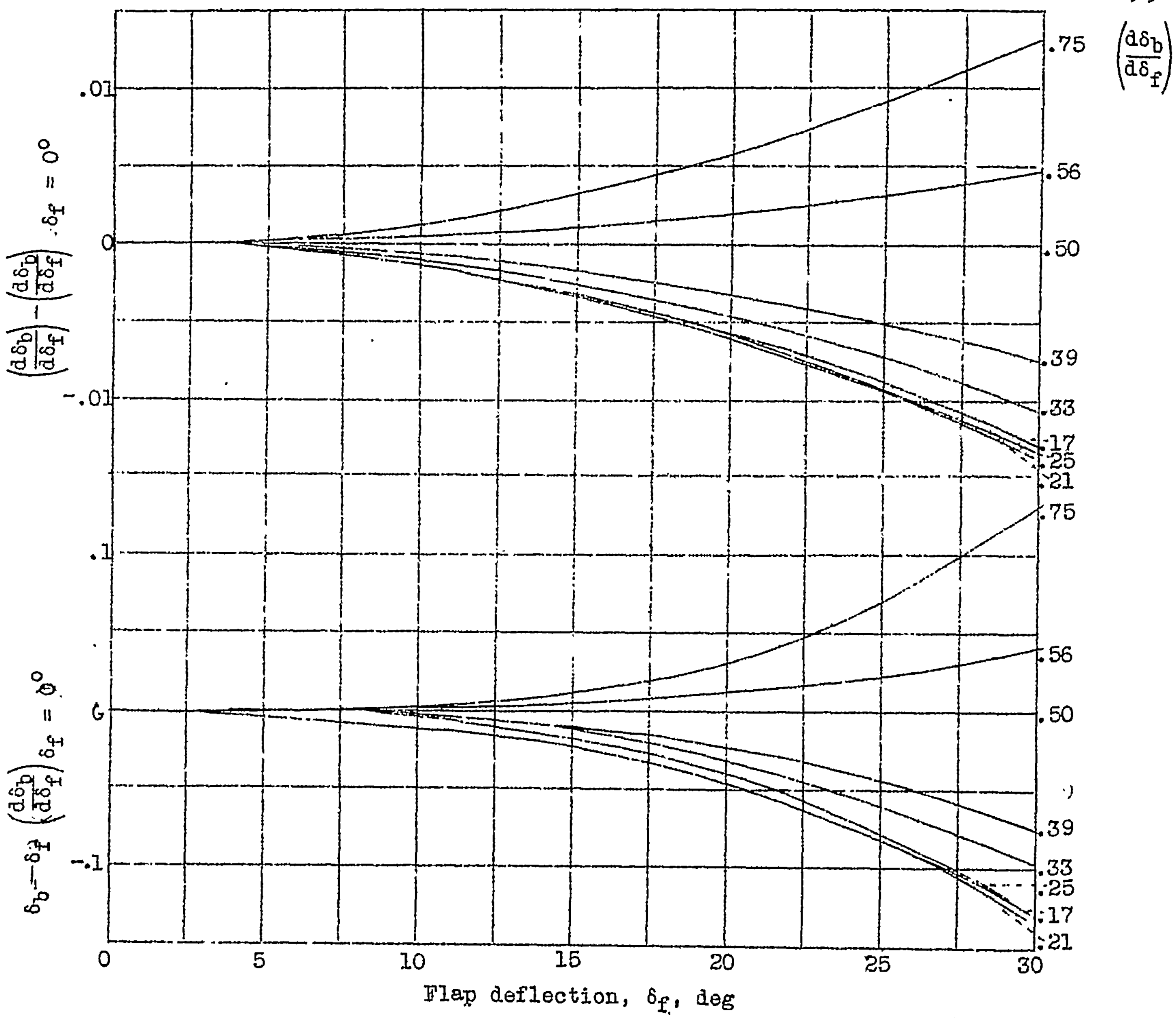
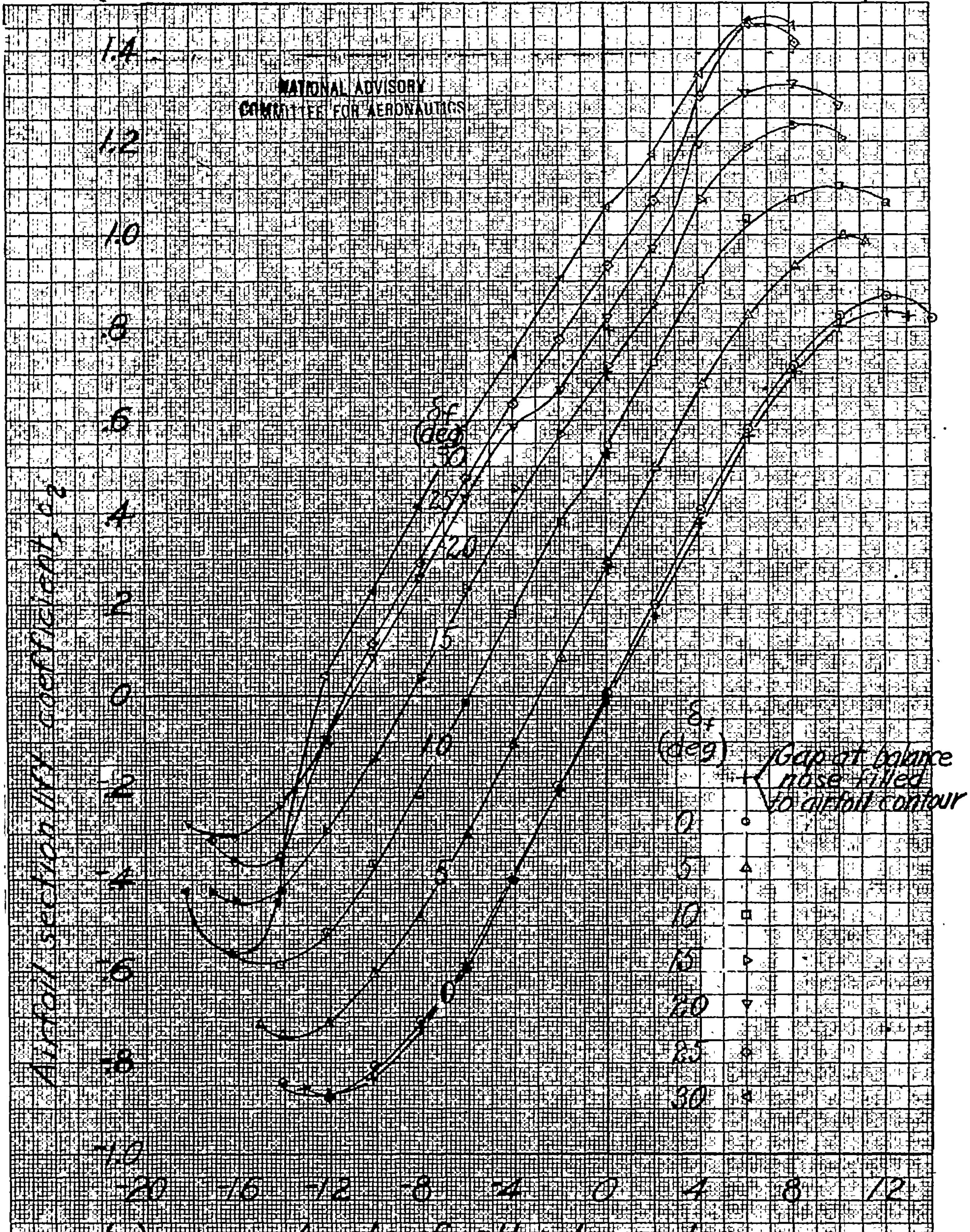


Figure 3.- Calculated characteristics of linkage systems.

NACA

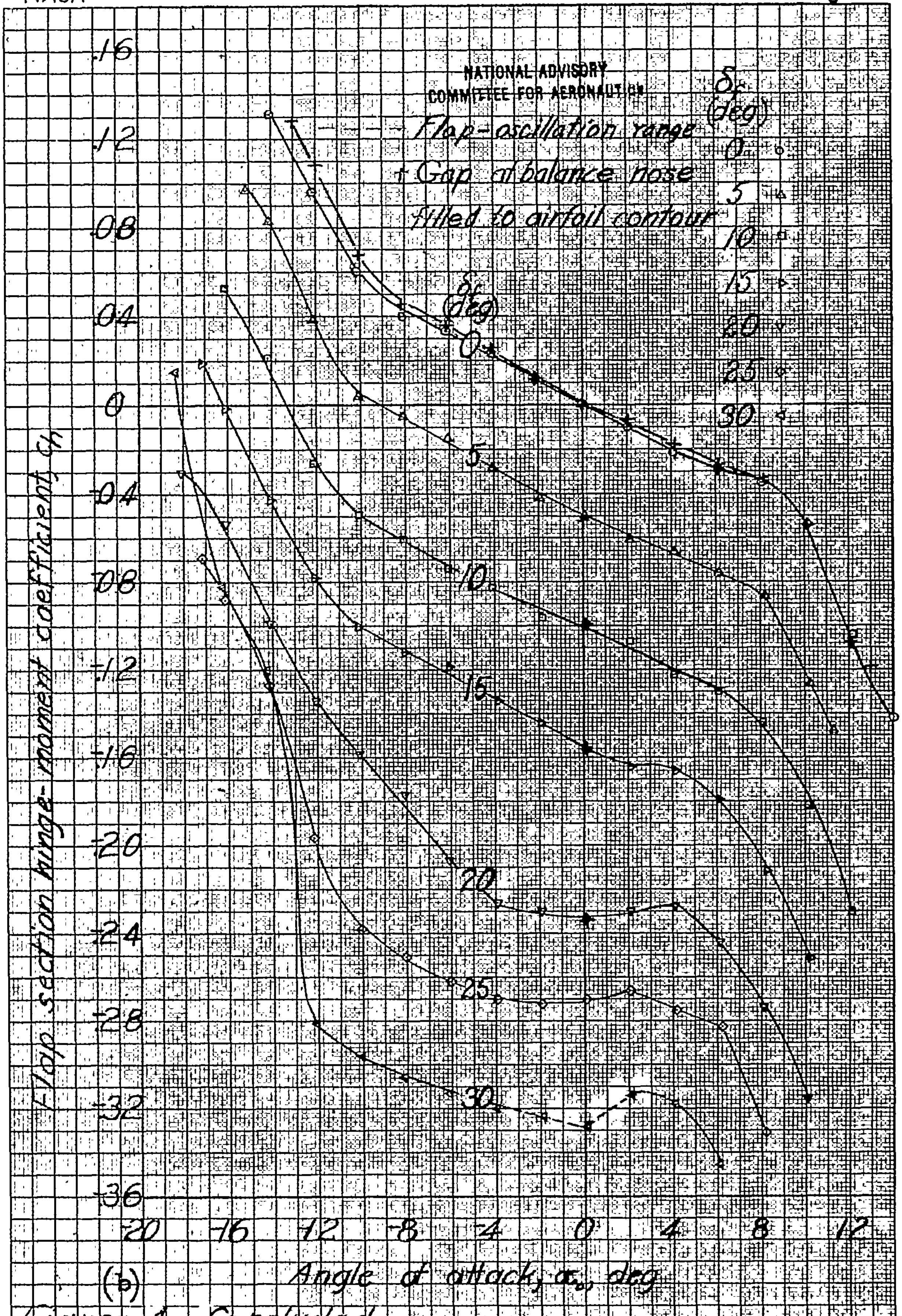
Fig. 3



(a)

Figure 4-Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour plain flap (simulated by c_b/c_f=0.75, t_b/c_f=0). Sealed gap.

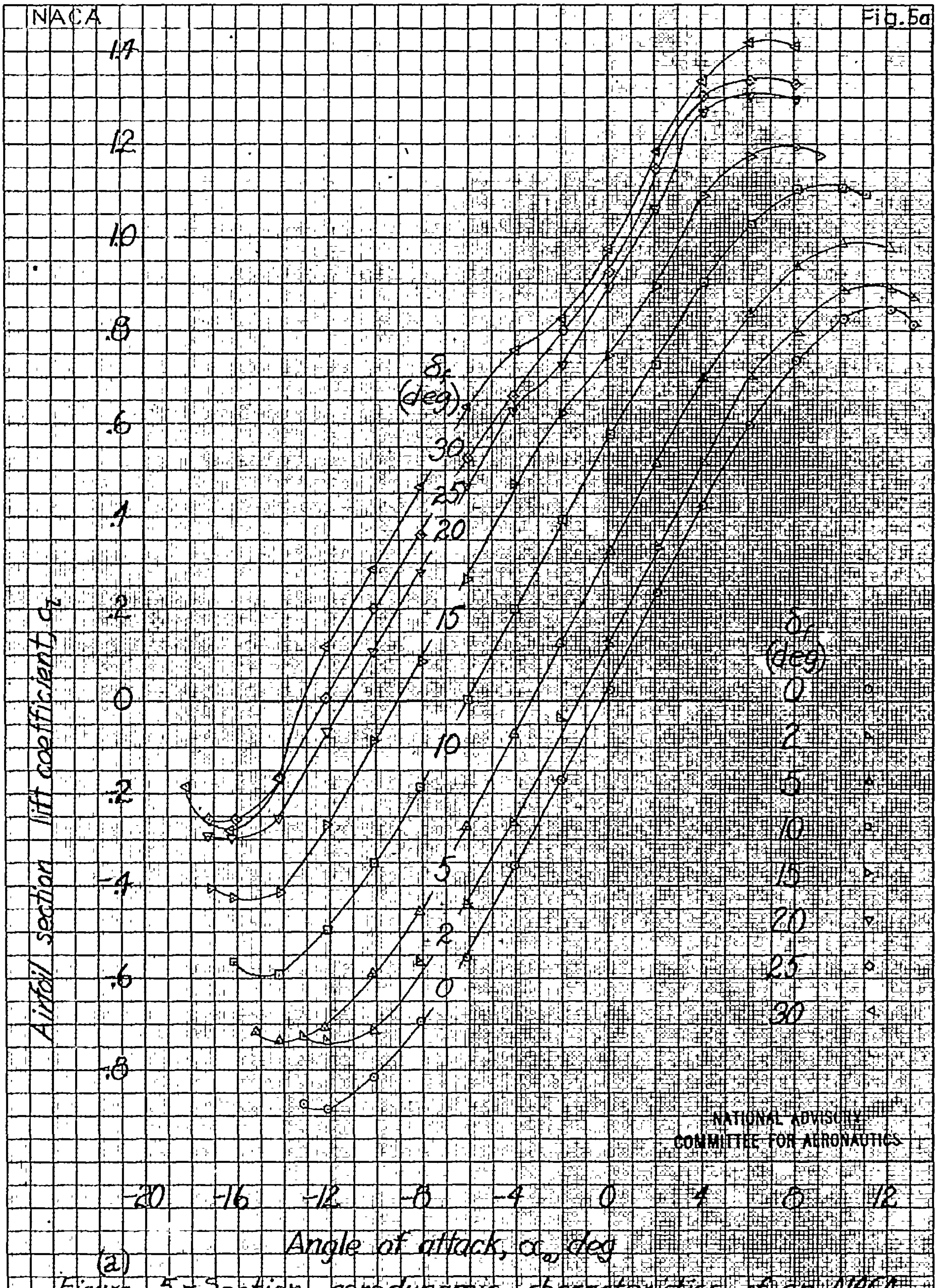
L-350



(b)

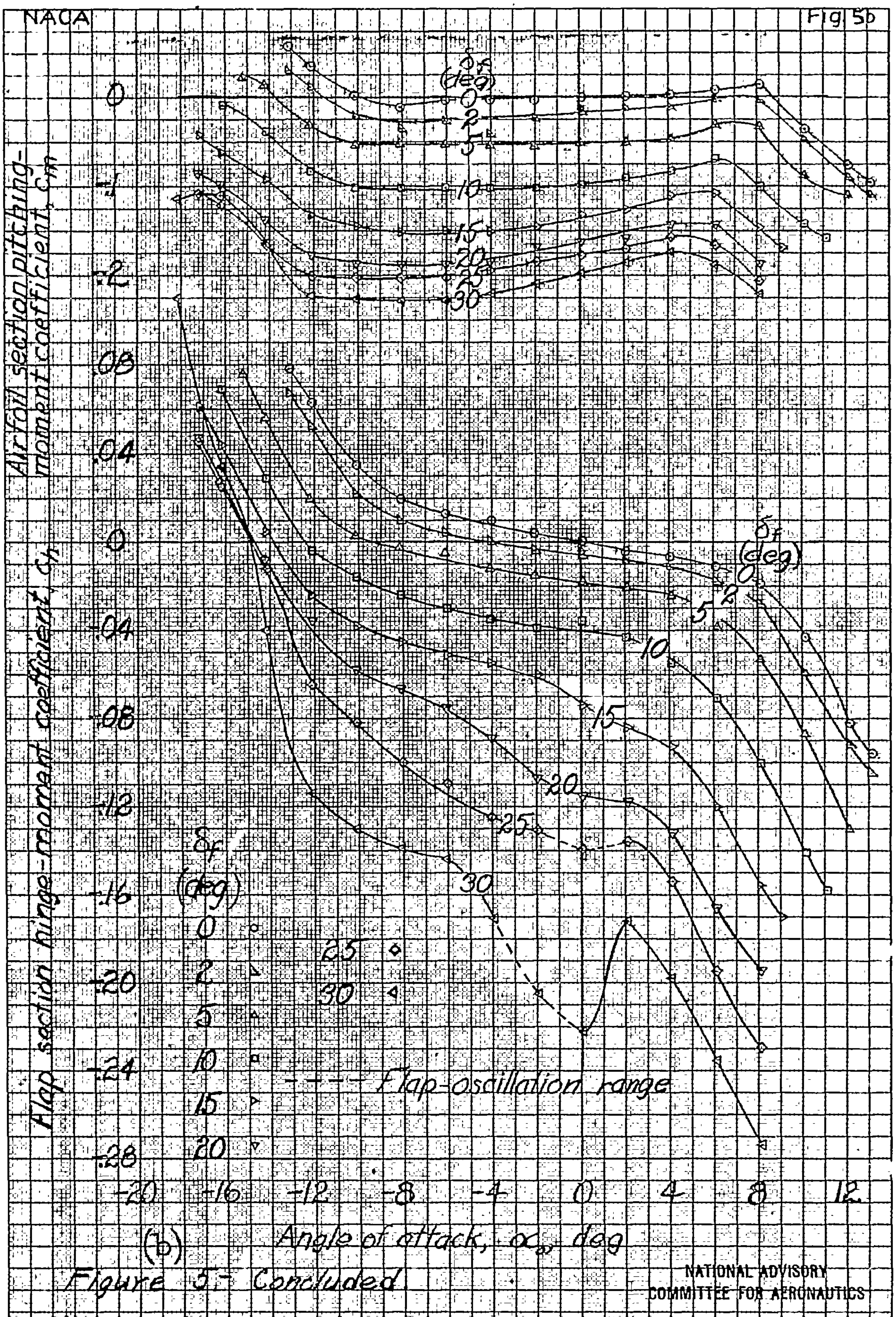
Figure 4.- Concluded.

L-350



(a)

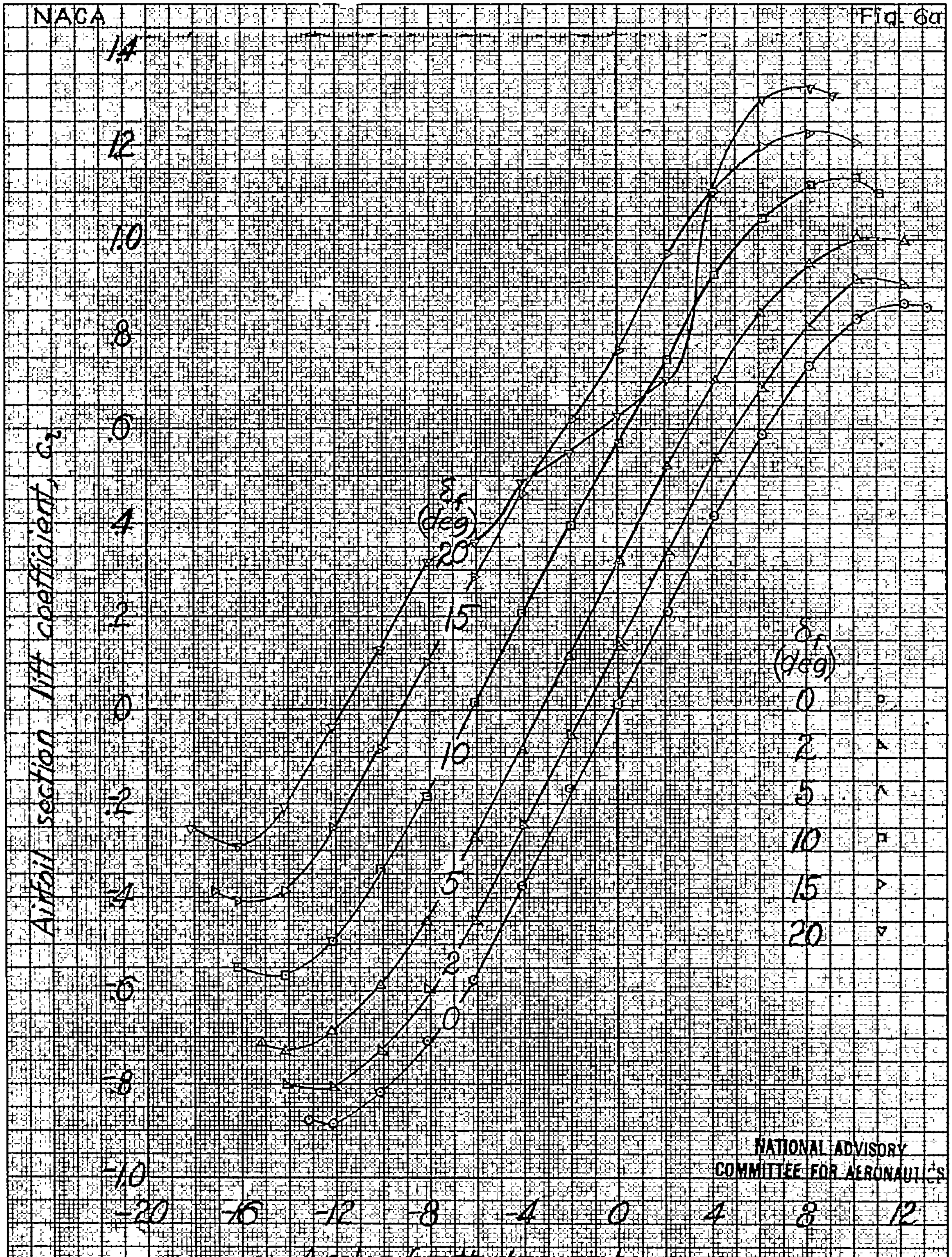
Figure 5.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight contour flap having a linked balance. c_b/c_f = 0.50; δ_b/δ_f = 0.56; sealed gap.



(b)

Figure 5.- Concluded.

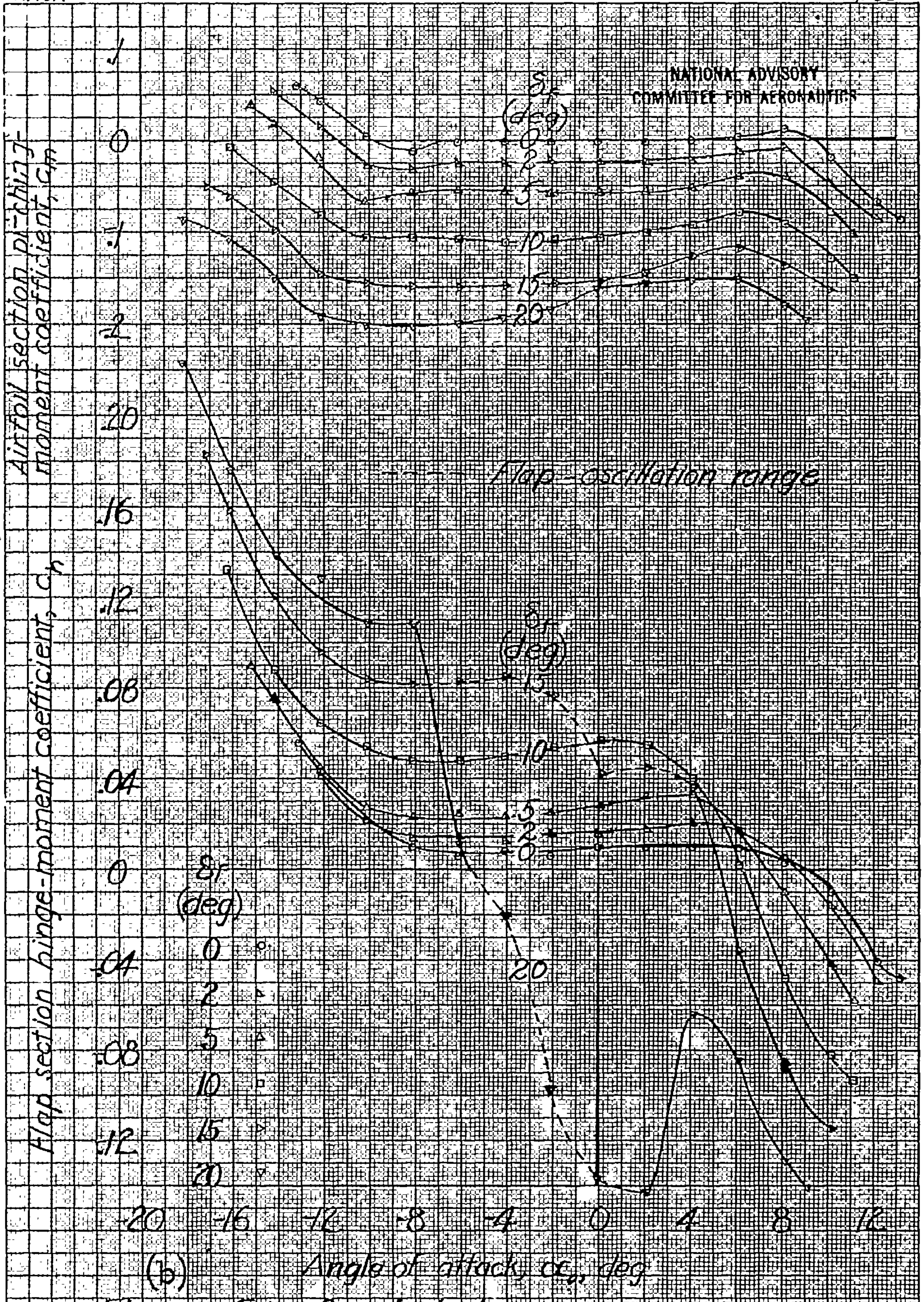
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS



(a)

Figure 6.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance $c_b/c_f = 0.50$; $d\delta_b/d\delta_f = 1.00$; sealed gap.

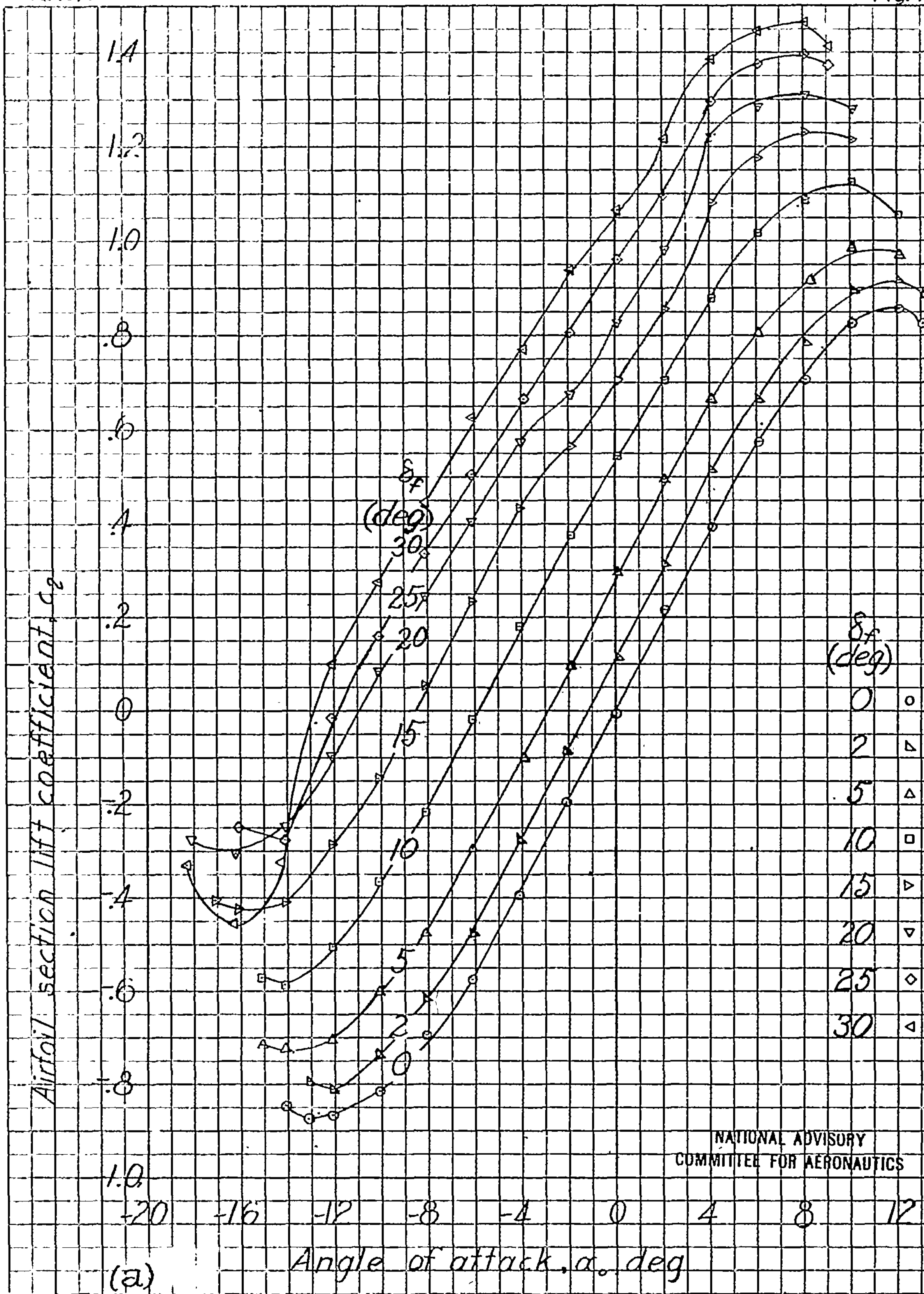
L-350



(b)

Figure 6.- Concluded.

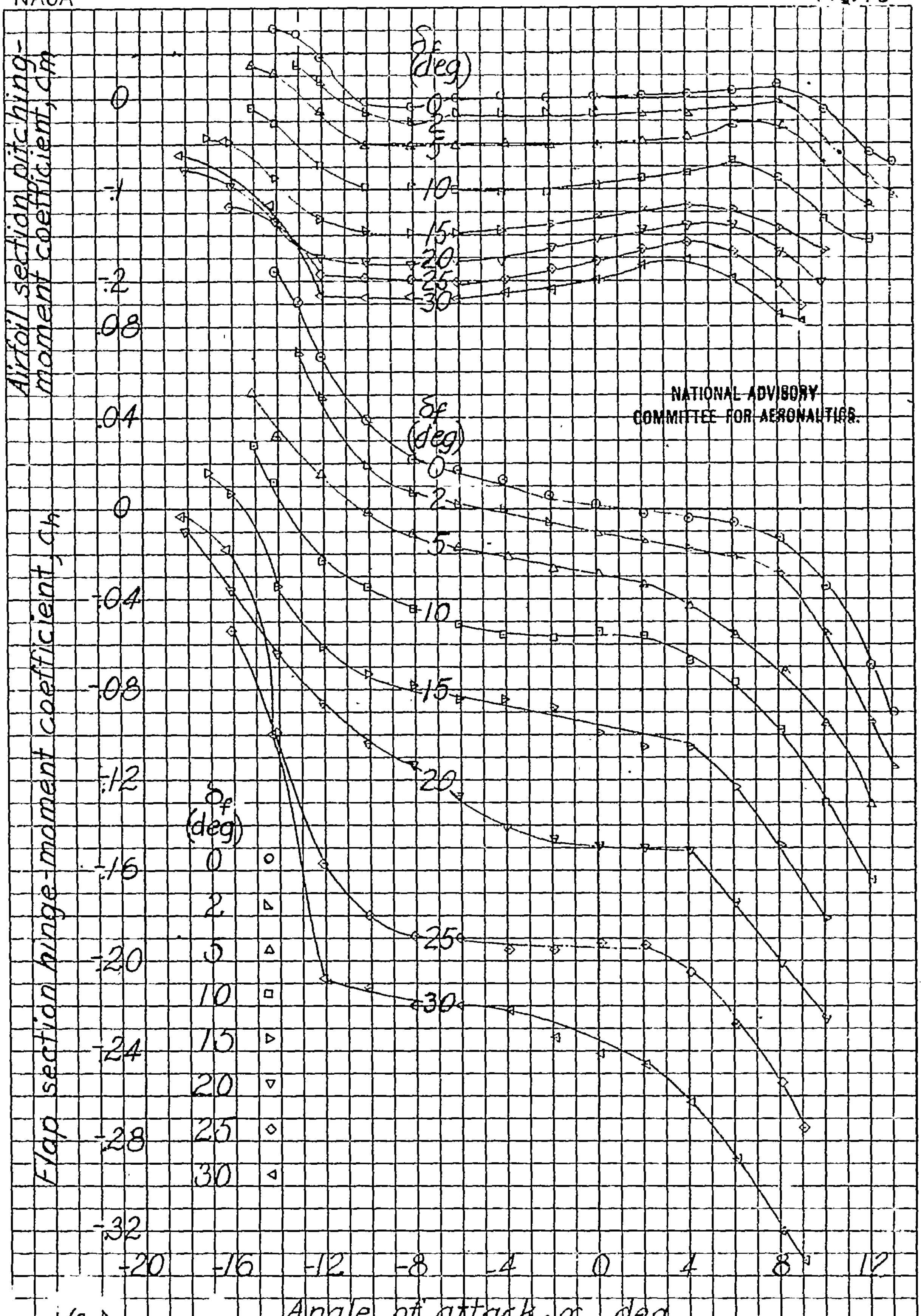
L-350



(a)

Figure 7.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance $c_b/c_f = 0.75$; $d\delta_b/d\delta_f = 0.21$; gap sealed.

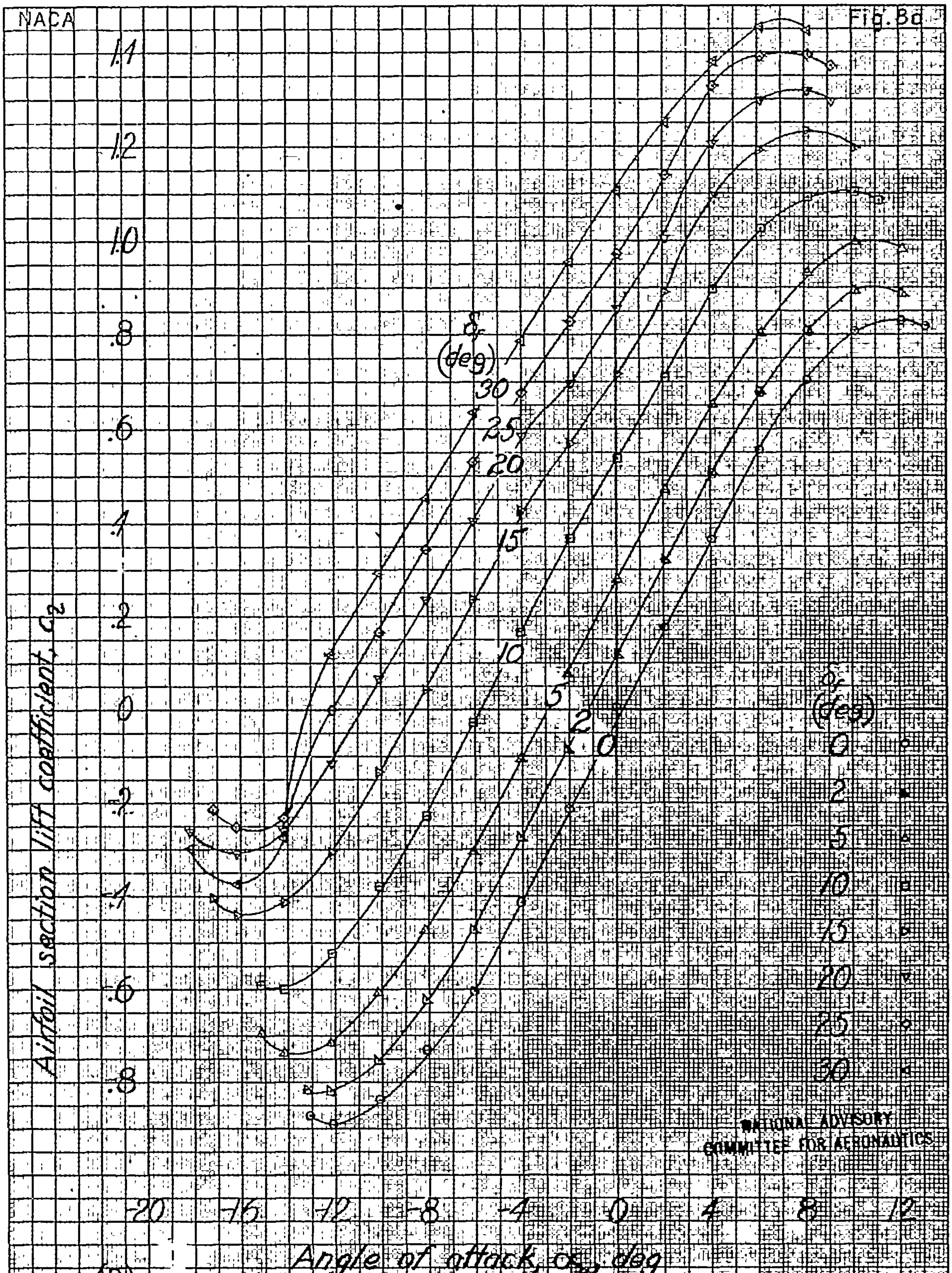
L-350



(b)

Figure 7.- Concluded.

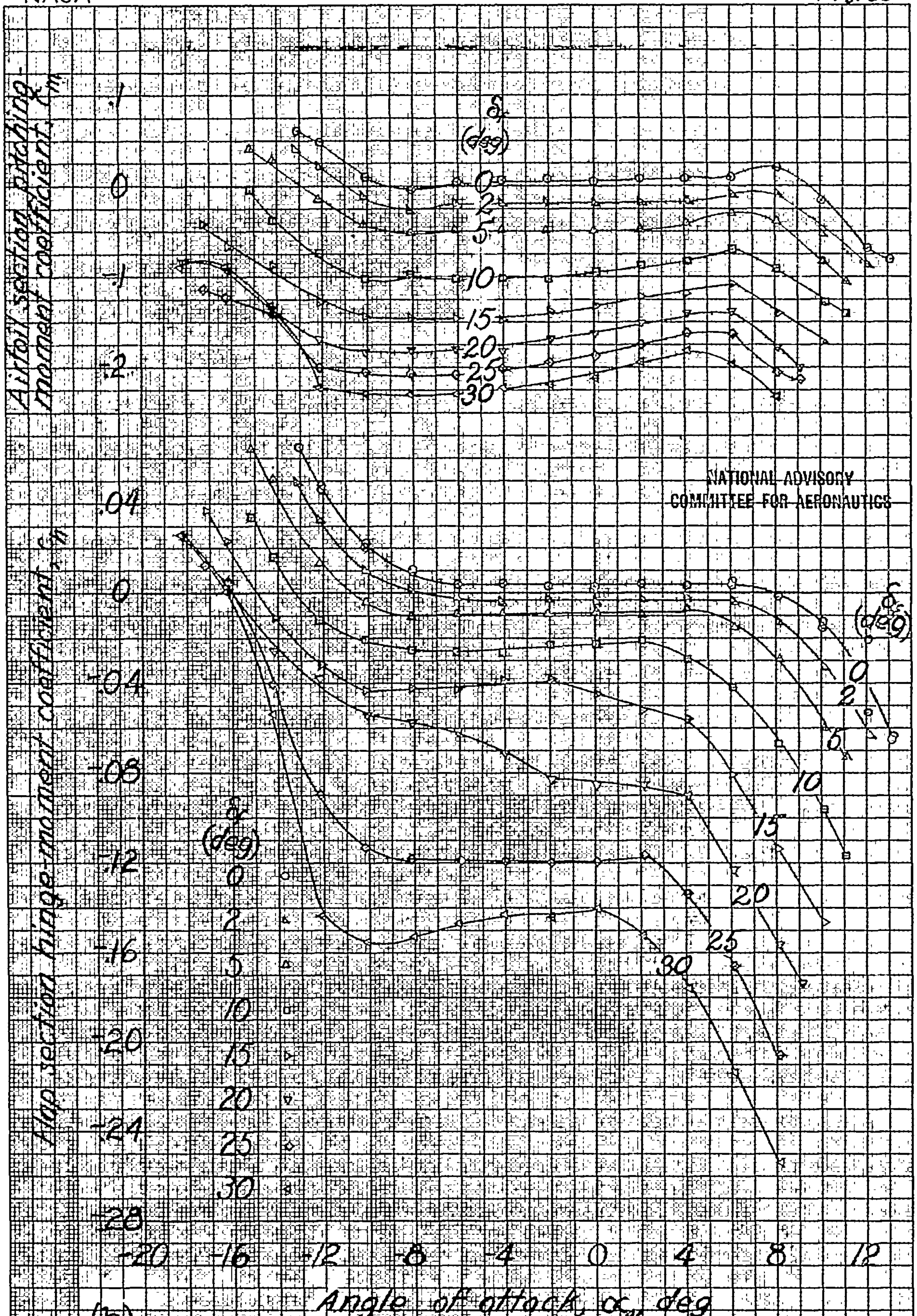
L-350



(a)

Figure 8.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. $c_b/c_f = 0.15$; $d\delta_t/d\delta_f = 0.33$; sealed gap.

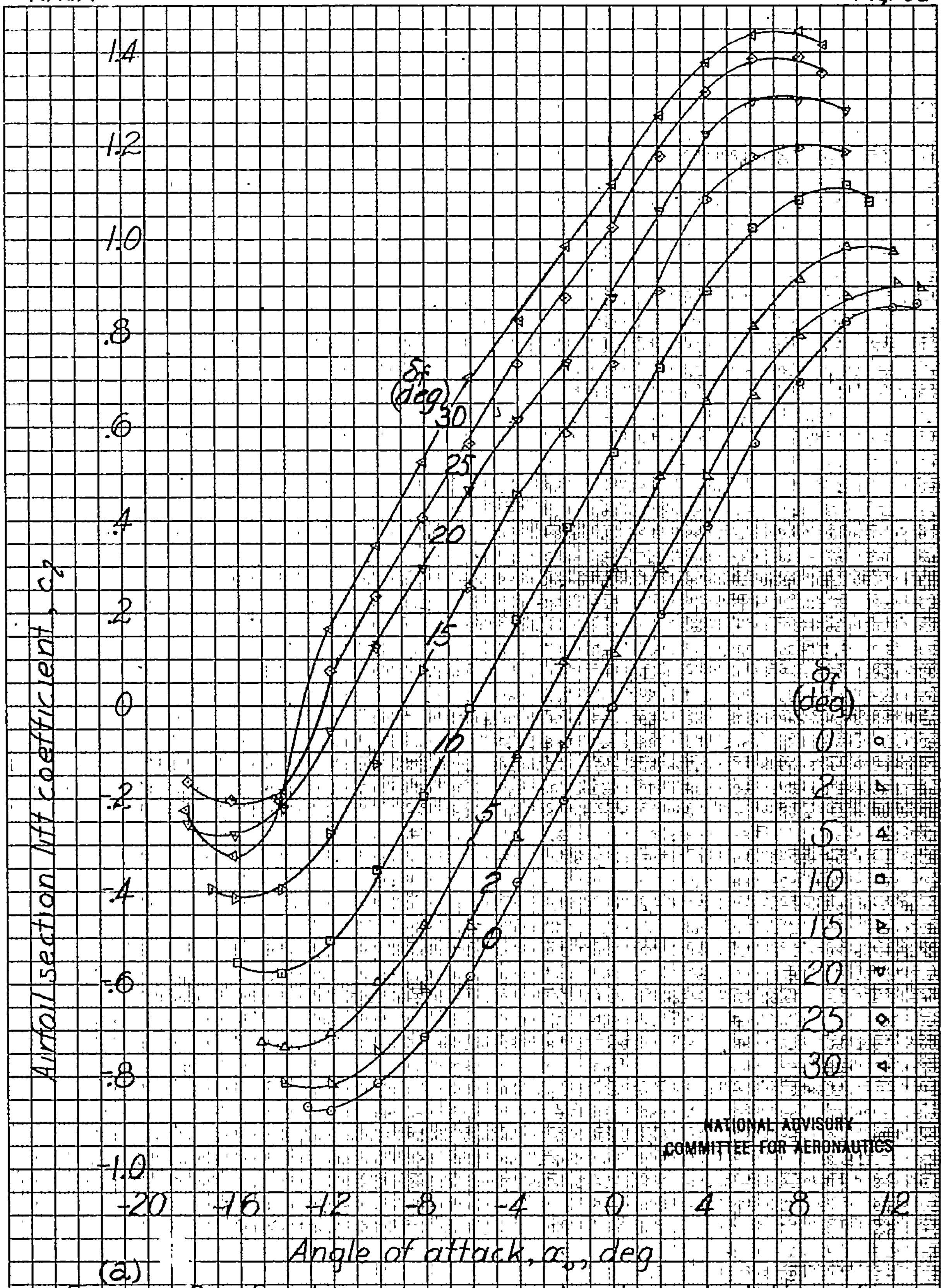
L-350



(b)

Figure 8.- Concluded.

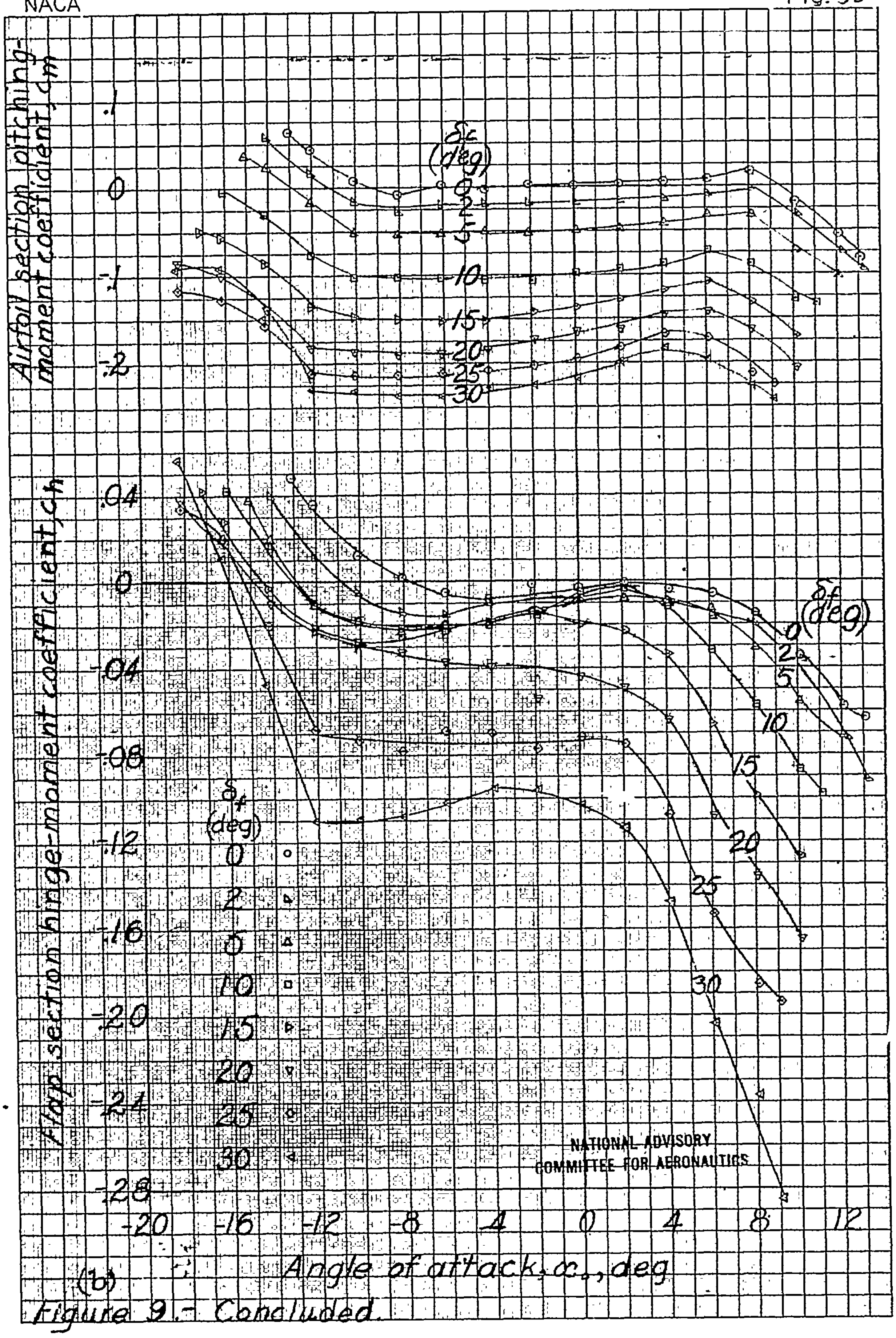
L-350



(a)

Figure 9.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance $c_b/c_f = 0.75$; $d\delta_b/d\delta_f = 0.39$, sealed gap.

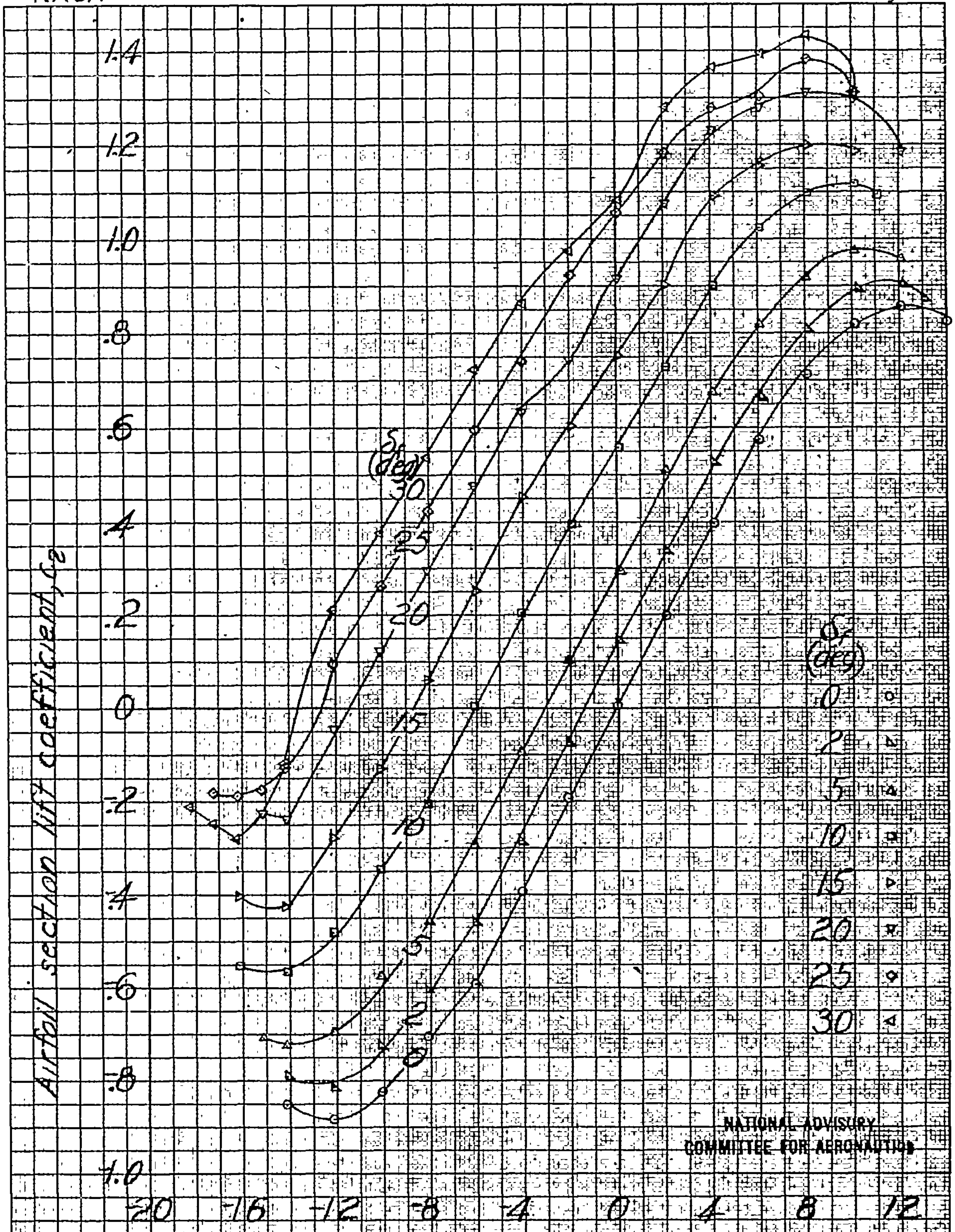
L-350



(b)

Figure 9.- Concluded.

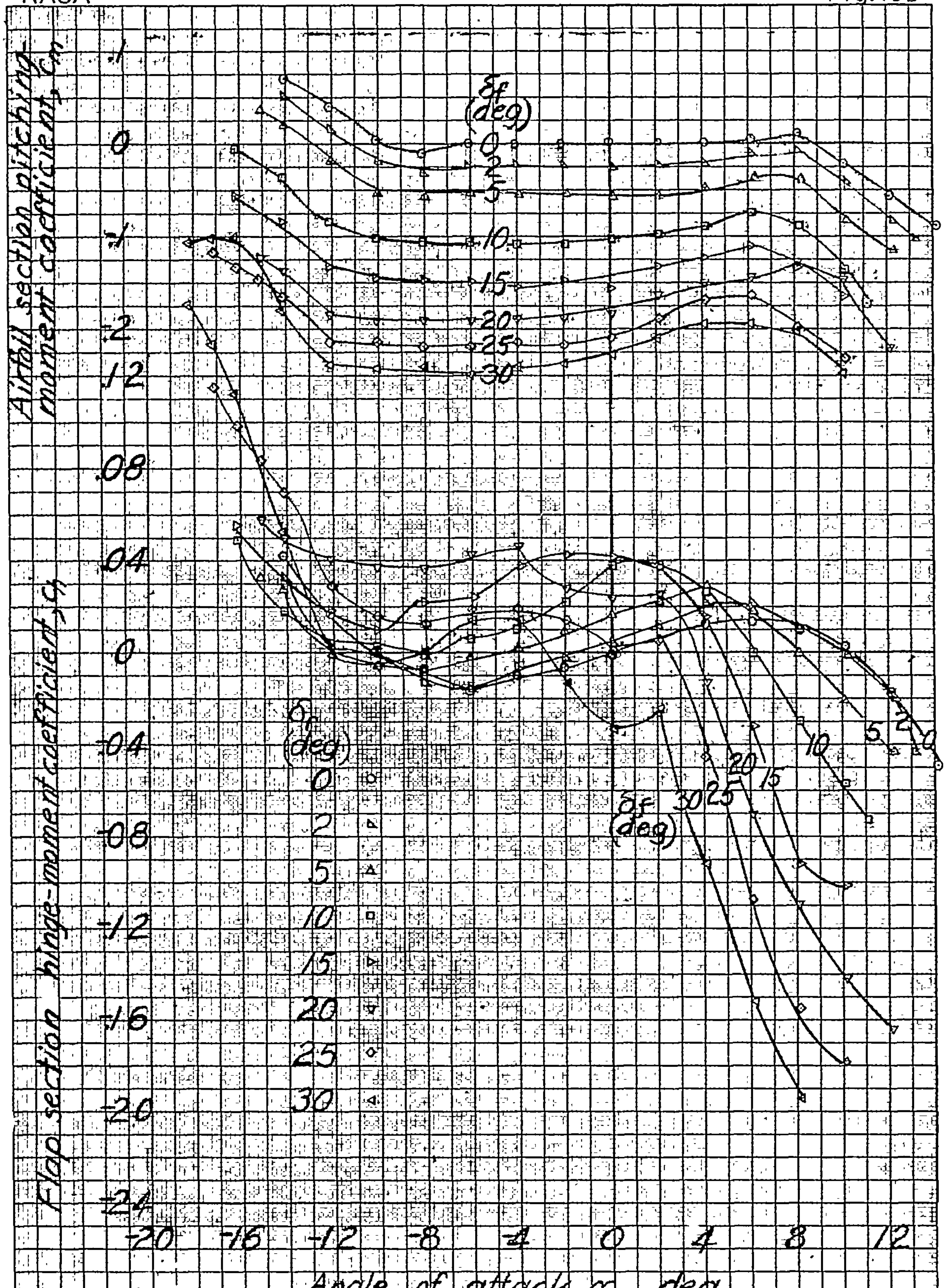
L-350



(a)

Figure 10-Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance c_b/c_f=0.75; $d\delta_b/d\delta_f$=0.50; gap sealed.

L-350

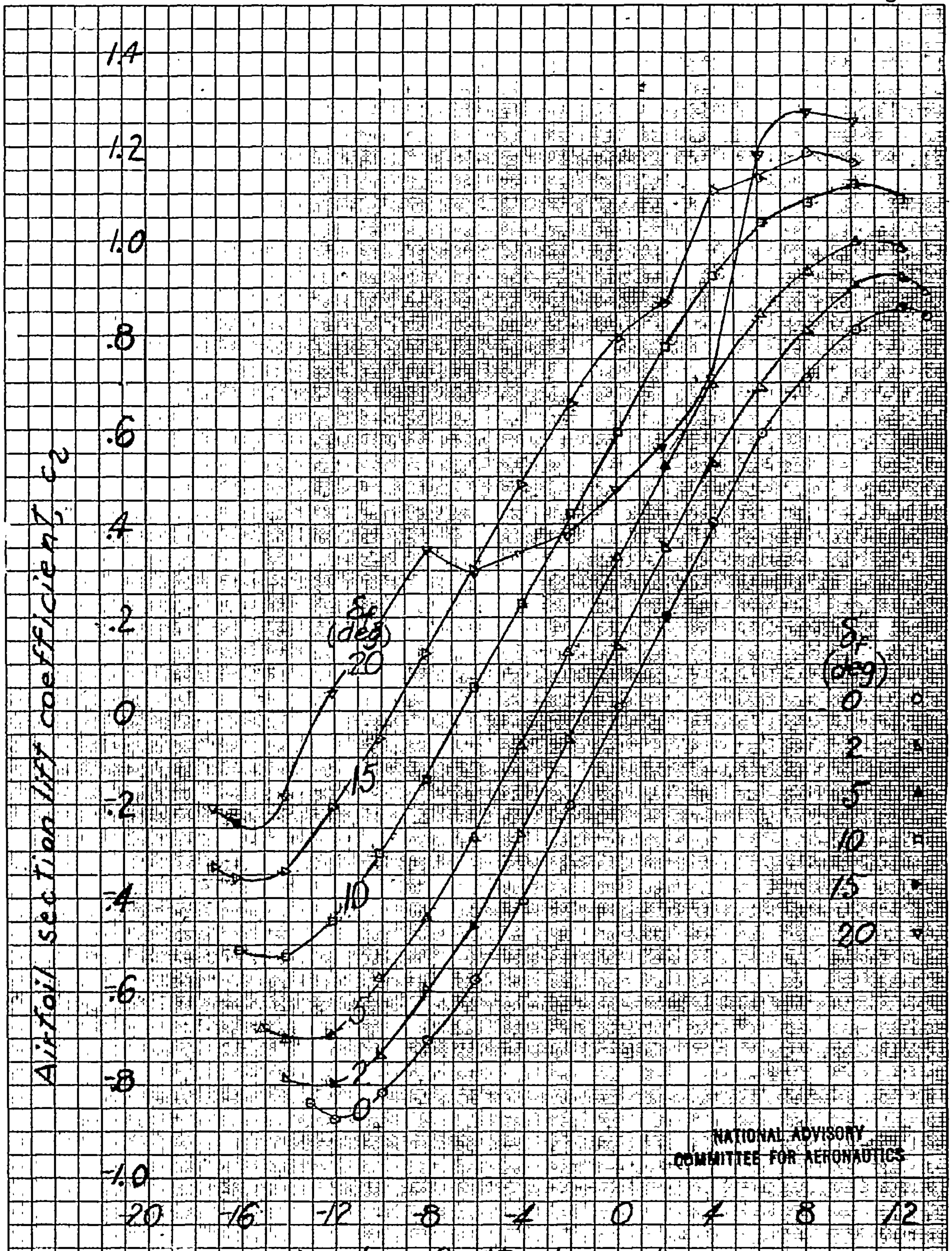


(b)

Figure 10 - Concluded.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

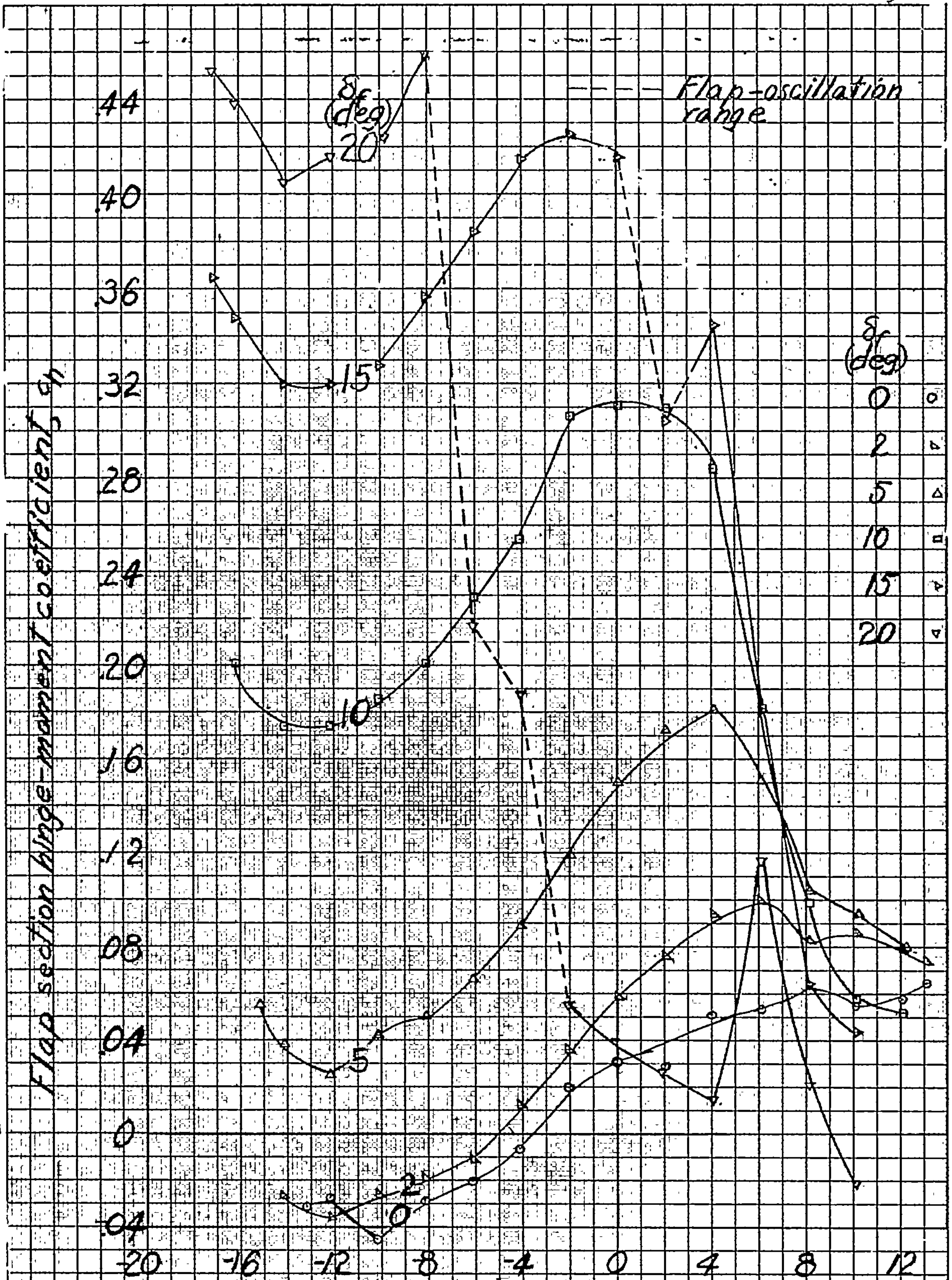
L-350



(a)

Figure 11- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. c_b/c_f = 0.75; $d\delta_b/d\delta_f$ = 1.00; sealed gap.

L-350

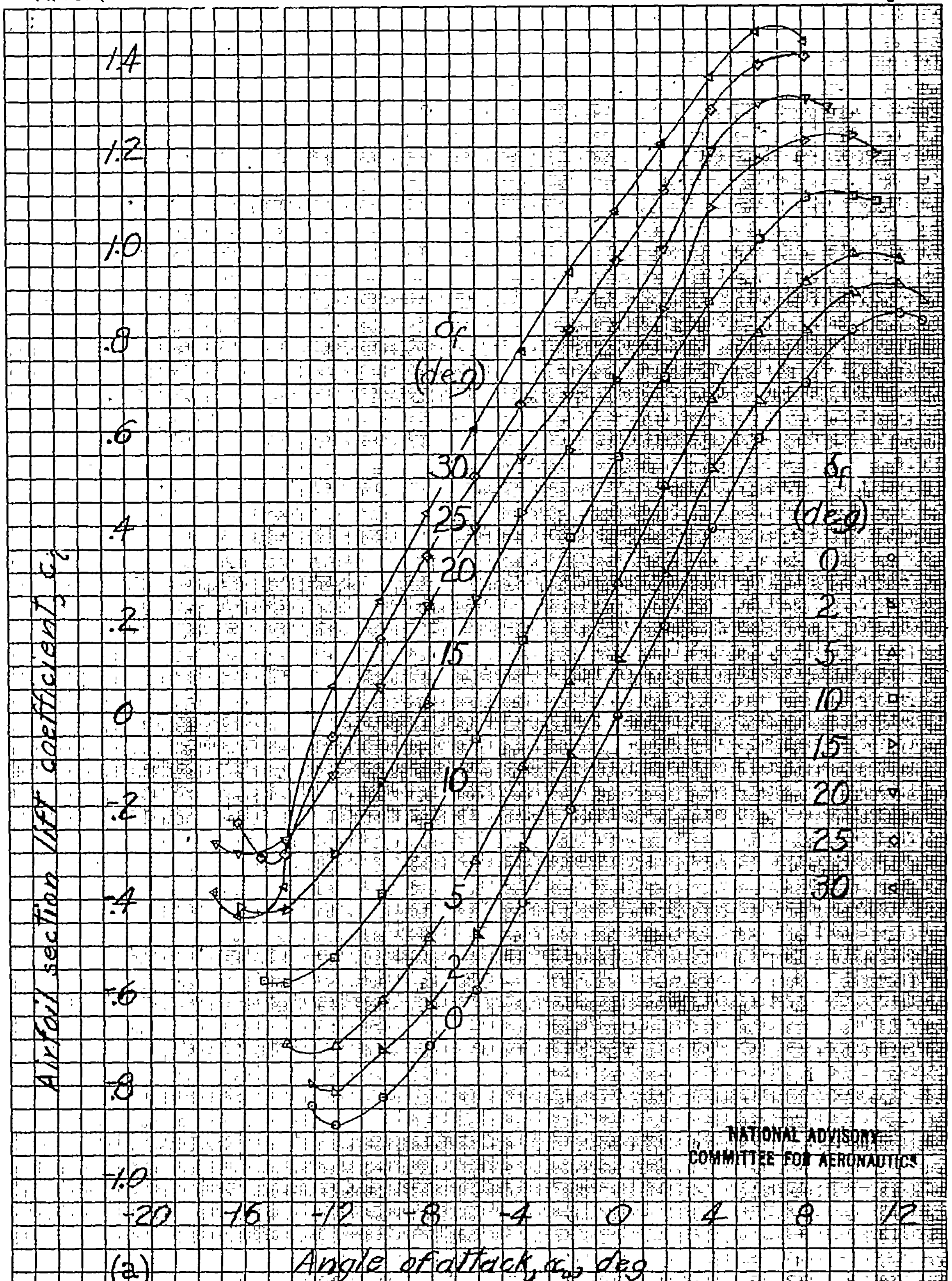


(b)

Figure 11.- Concluded.

L48

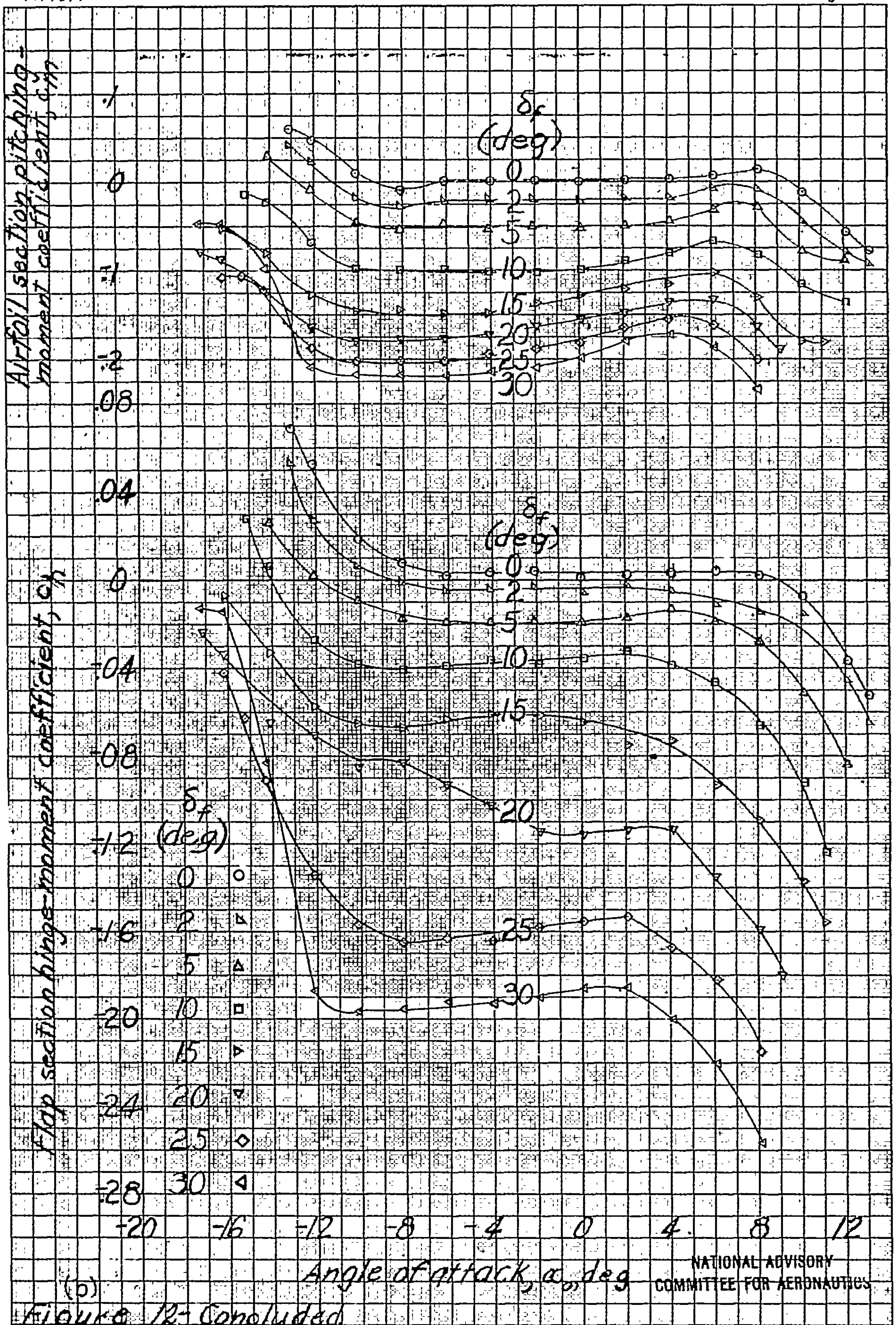
L-350



(a)

Figure 12.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. $\delta_b/\delta_f = 1.00$; $d\delta_b/d\delta_f = 0.17$; sealed gap.

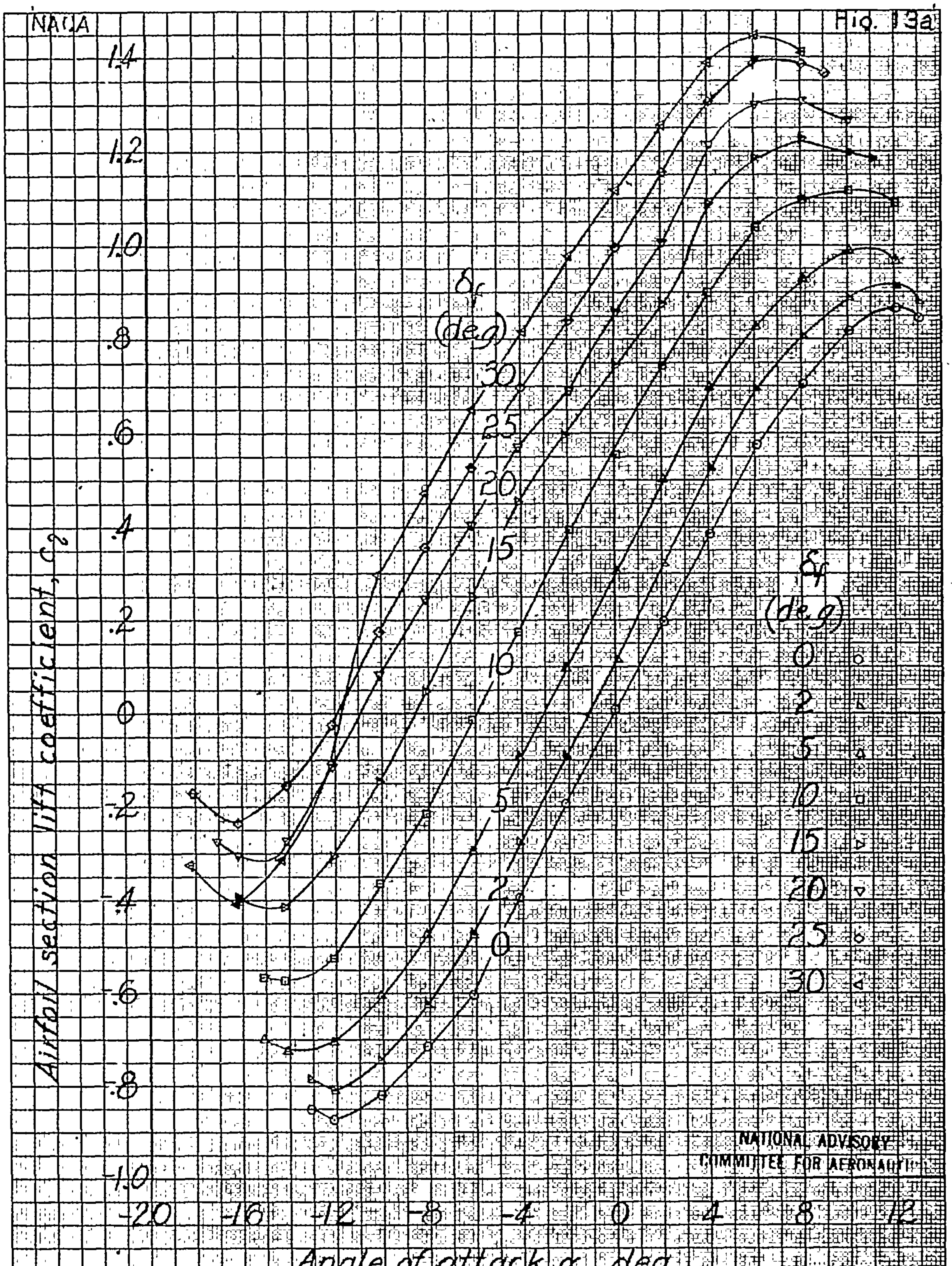
L-350



(b)

Figure 12.- Concluded

L-350



(a)

Figure 13.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. c_b/c_f = 1.00; $d\delta_b/d\delta_f$ = 0.25; sealed gap.

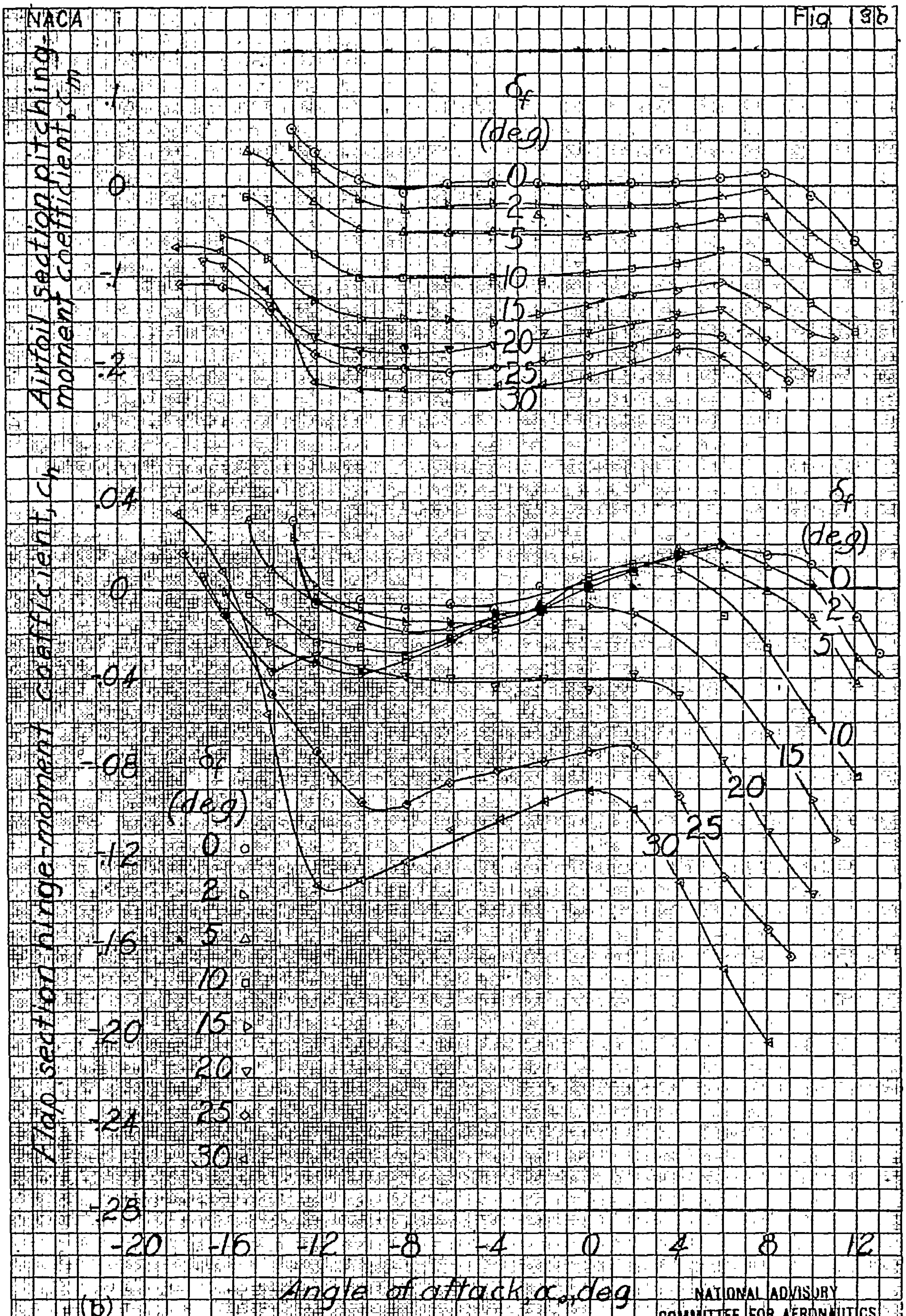
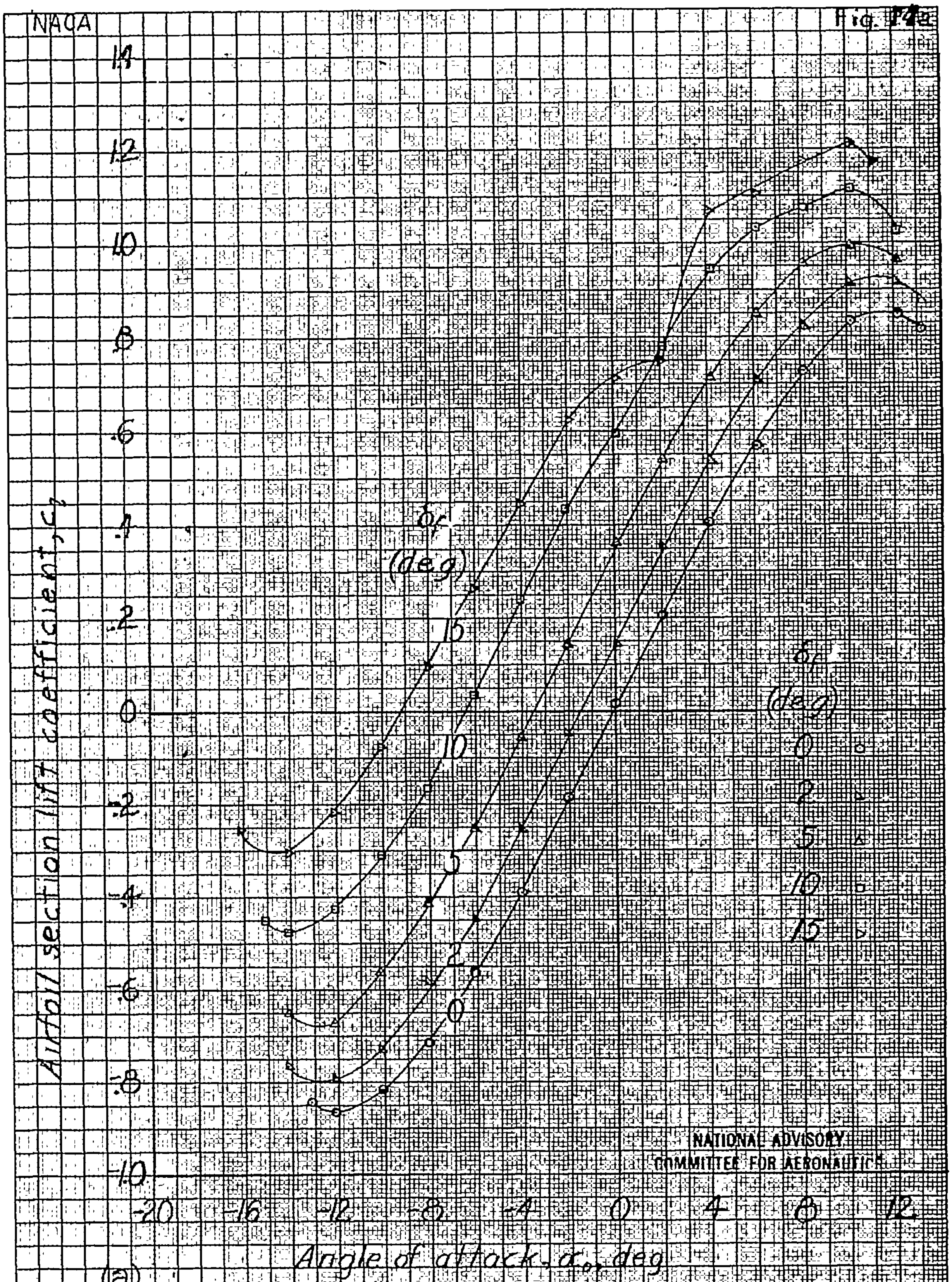


Figure 13.- Concluded.

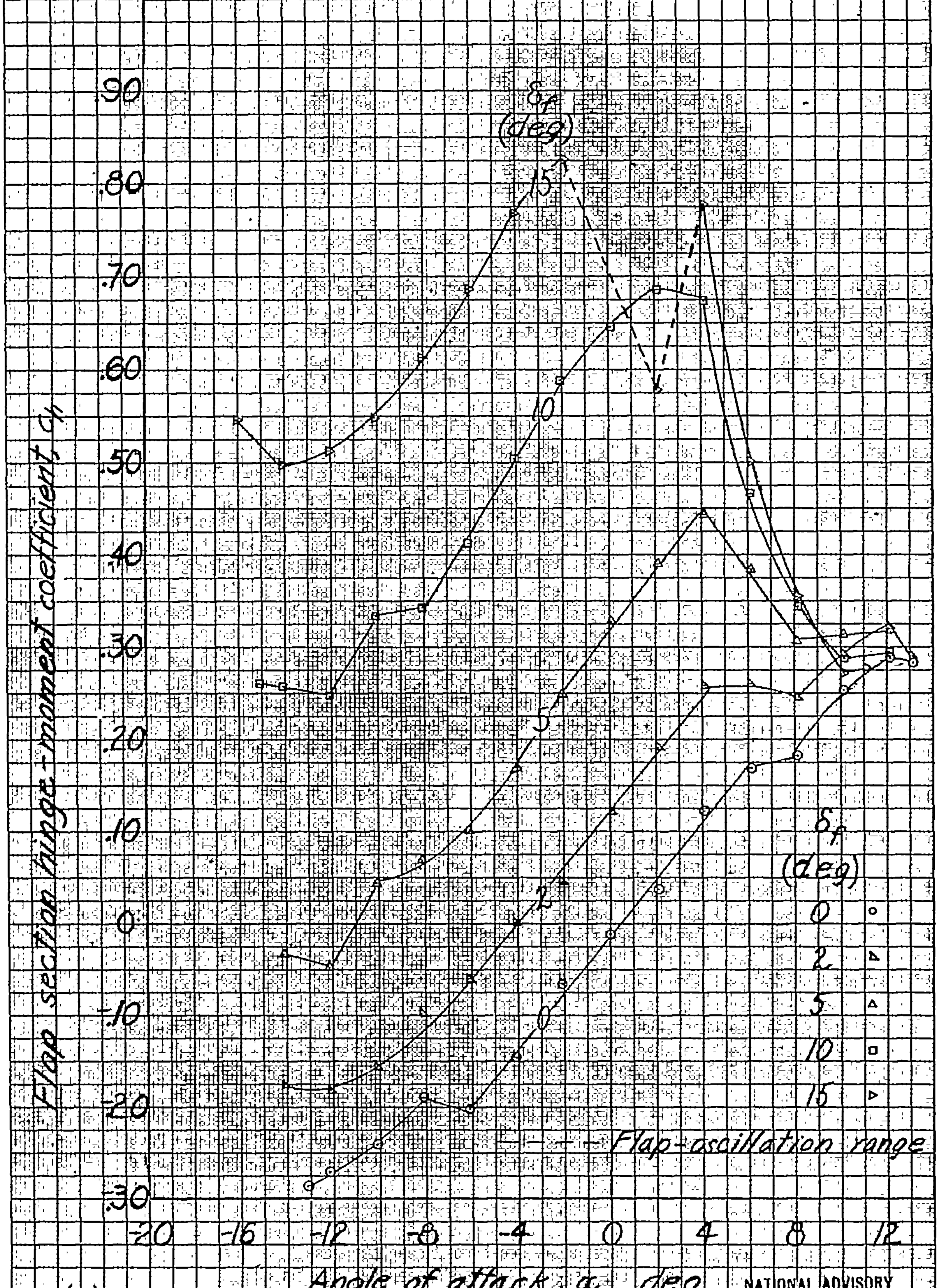
L-350



(a)

Figure 14-Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. c_b/c_f = 1.00; δ_b/δ_f = 1.00; sealed gap.

L-350

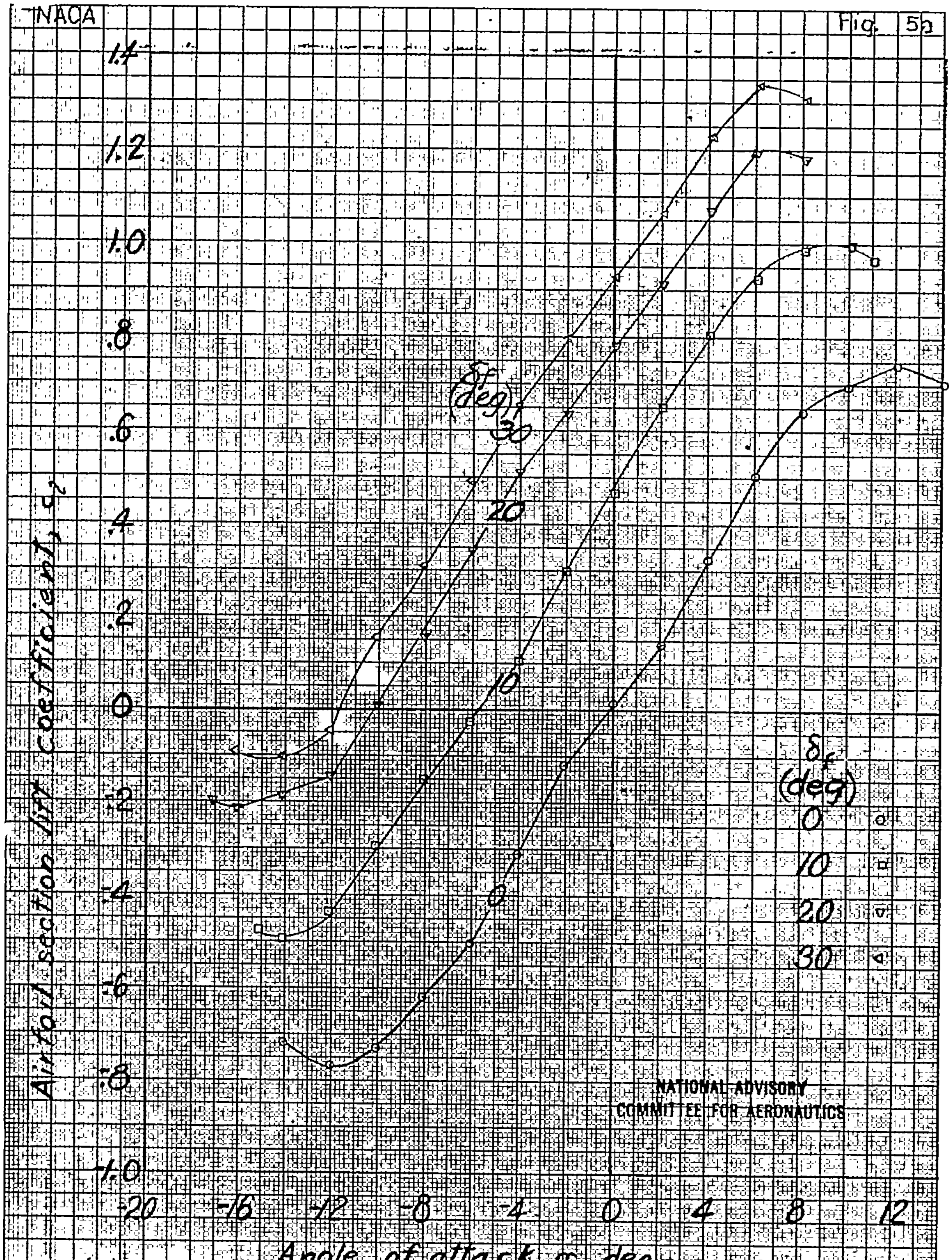


(b)

Figure 14- Concluded.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

L - 350

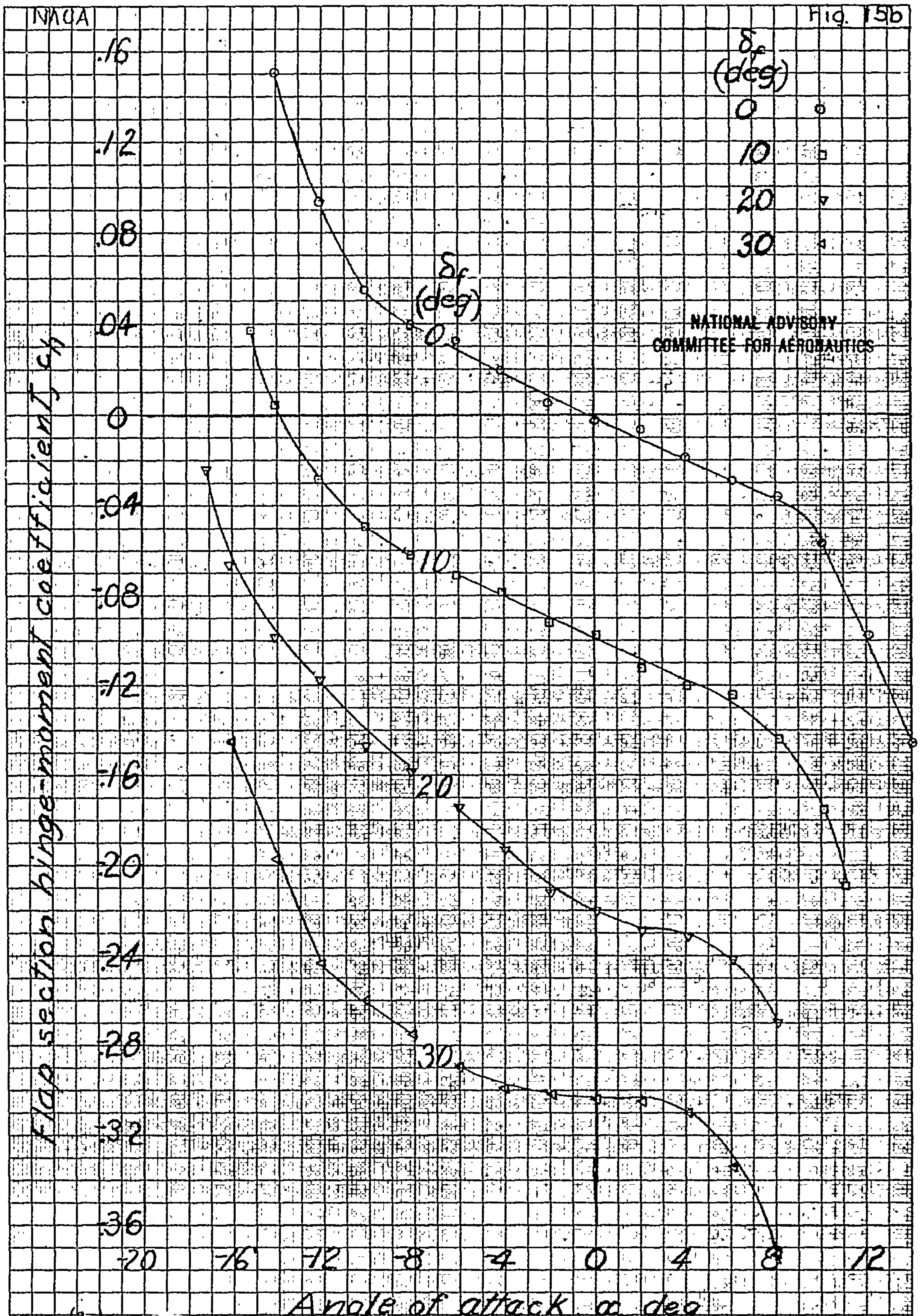


(a)

Figure 15-Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour plain flap (simulated by c_b/c_f=0.15, $d\delta_b/d\delta_f$=0) 0.005c gap.

L - 350

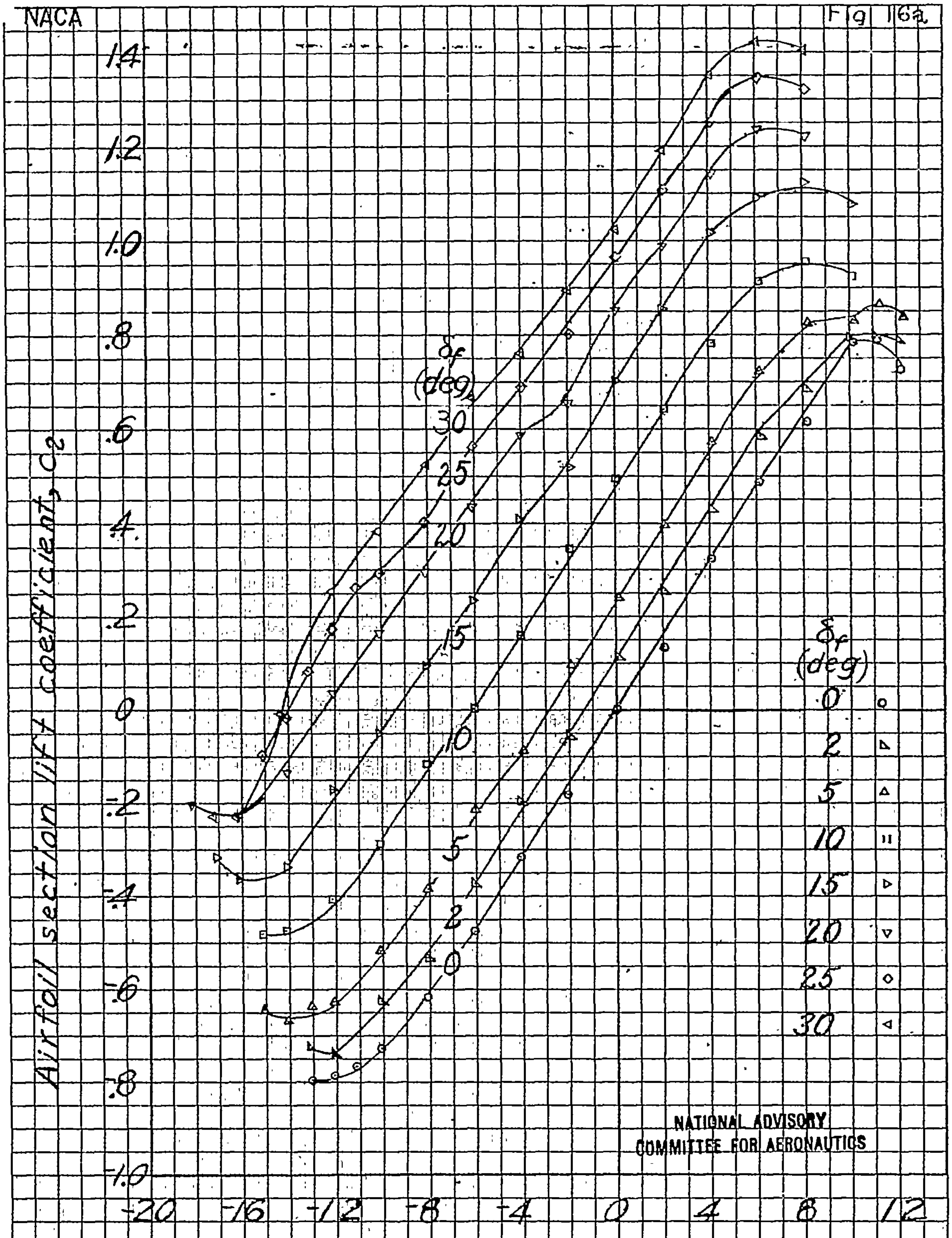
NACA Fig. 15b



(b)

Figure 15 - Concluded.

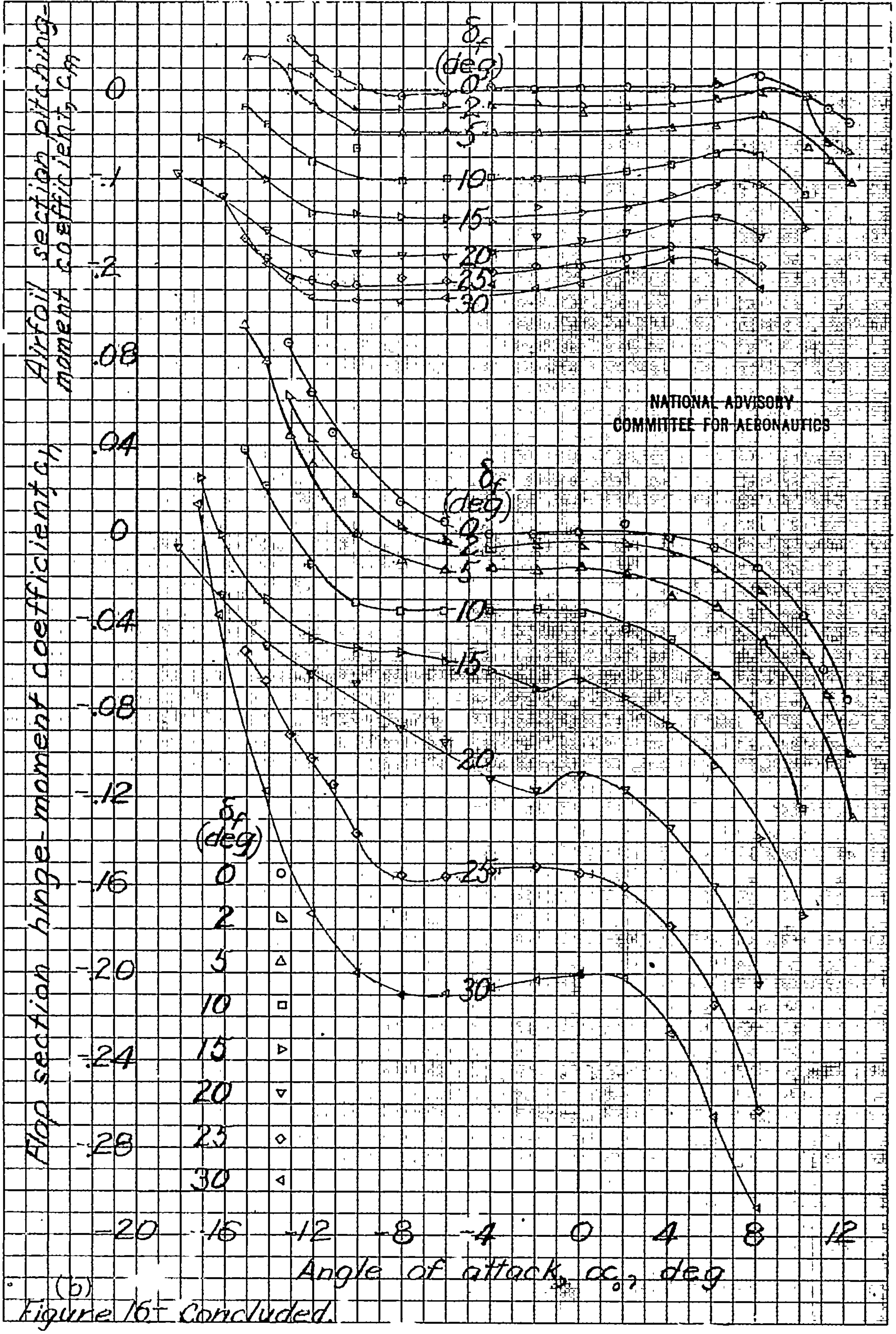
L - 350



(a)

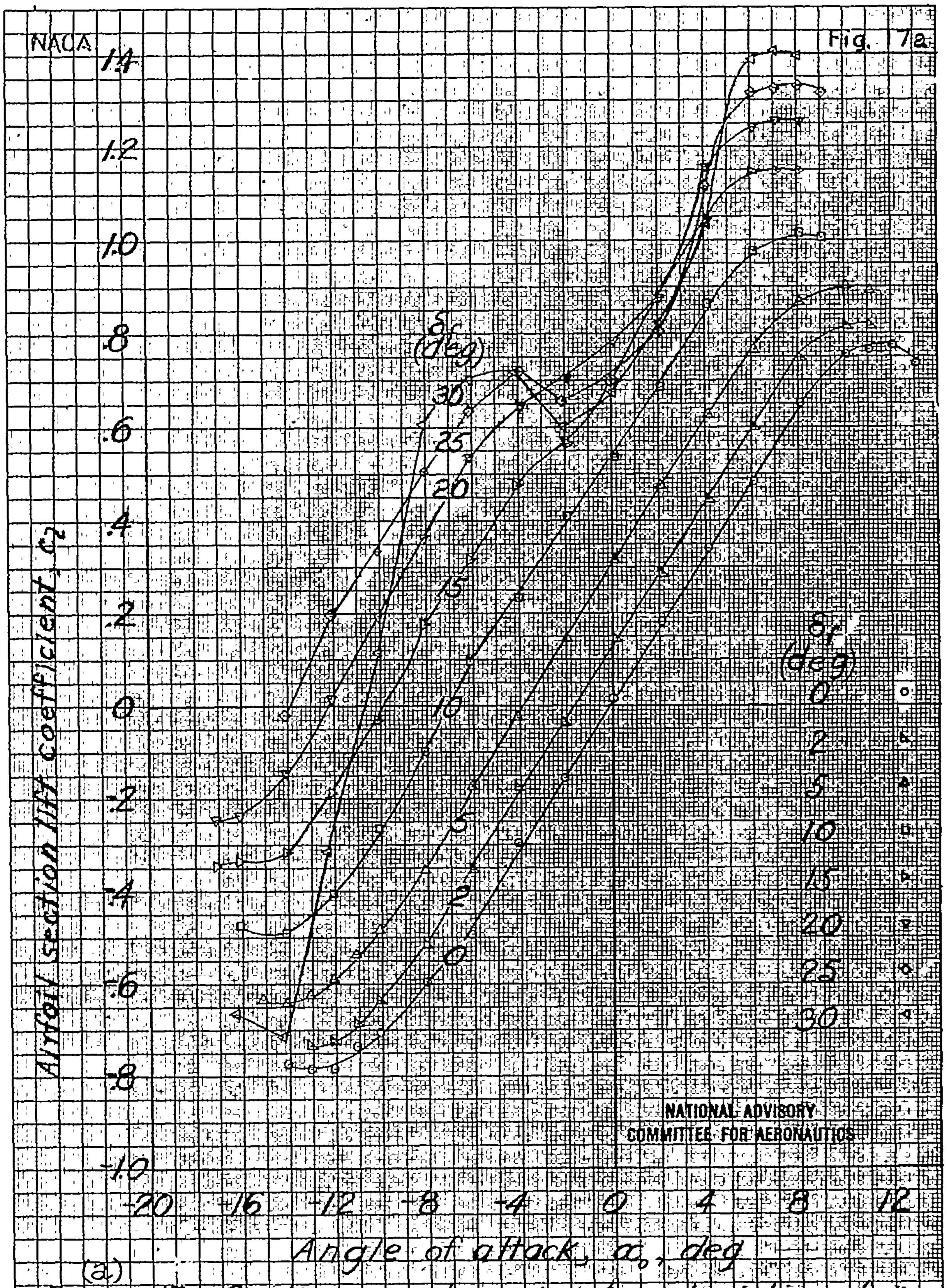
Figure 16.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. $c_b/c_f = 0.50$; $d\delta_b/d\delta_f = 0.50$; 0.0005c gap.

L - 350



(b)
Figure 16- Concluded.

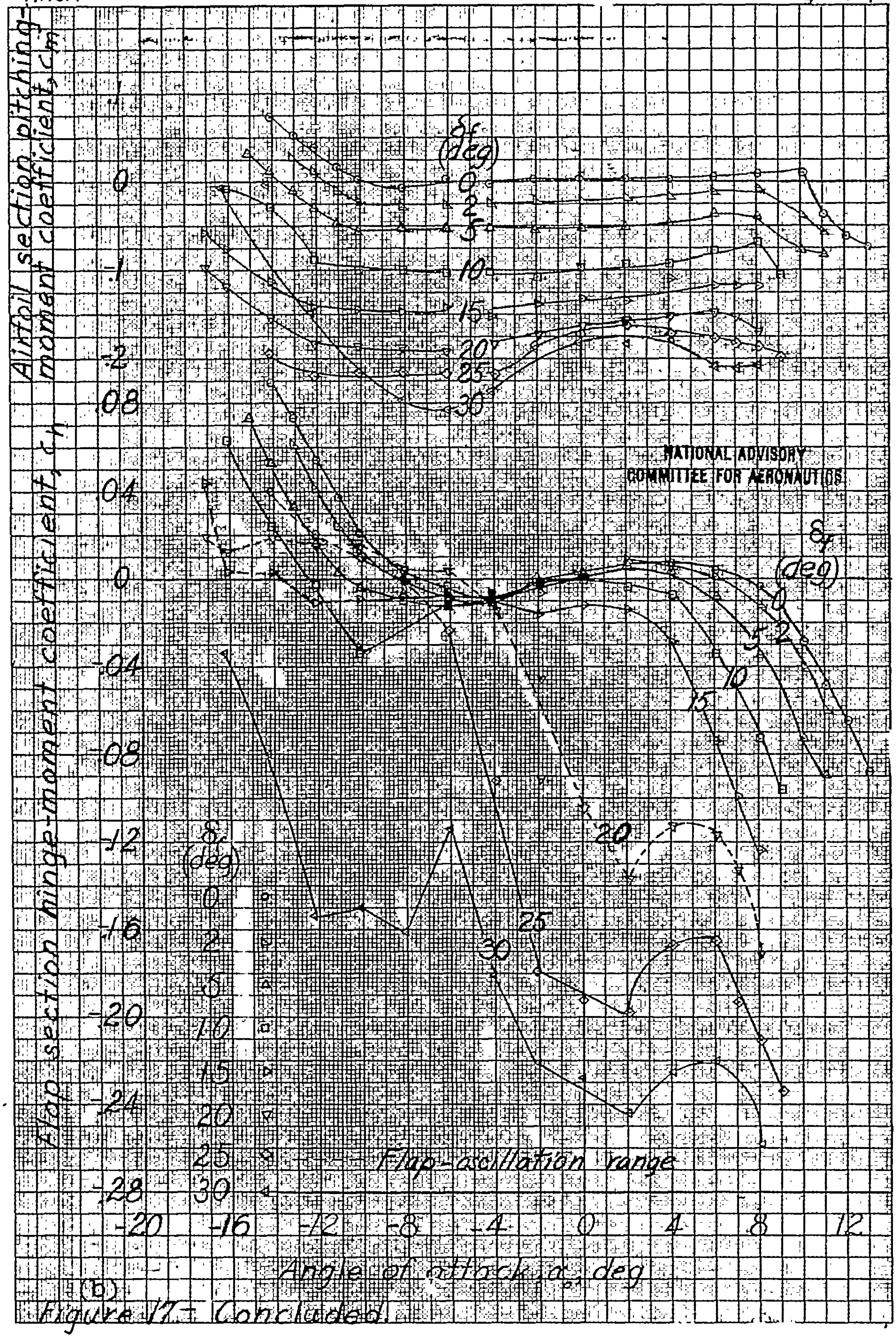
L - 350



(a)

Figure 17.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. c_b/c_f=0.50; $d\delta_b/d\delta_f$=0.75; 0.005c gap.

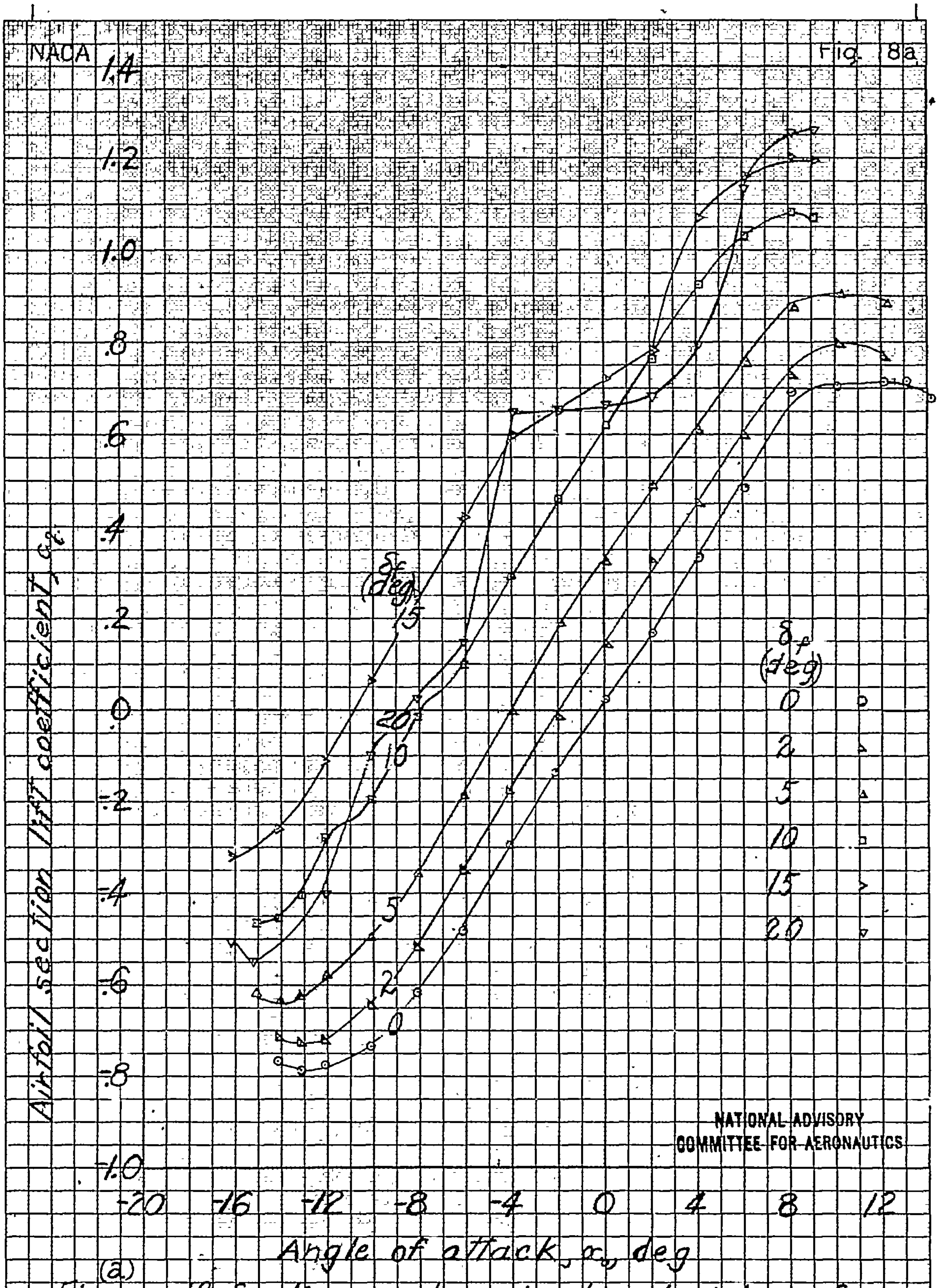
L - 350



(b)

Figure 17.- Concluded.

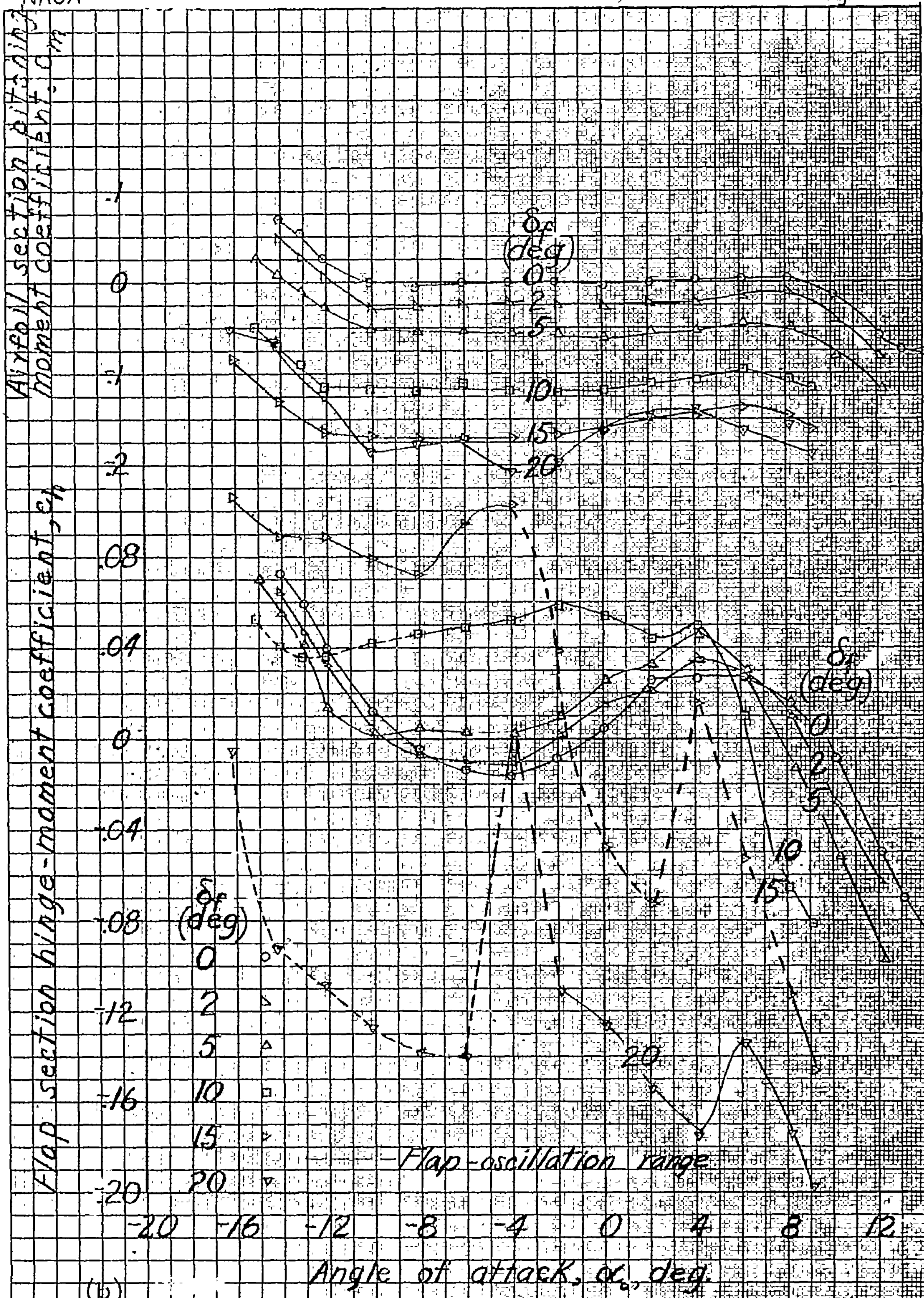
I - 350



(a)

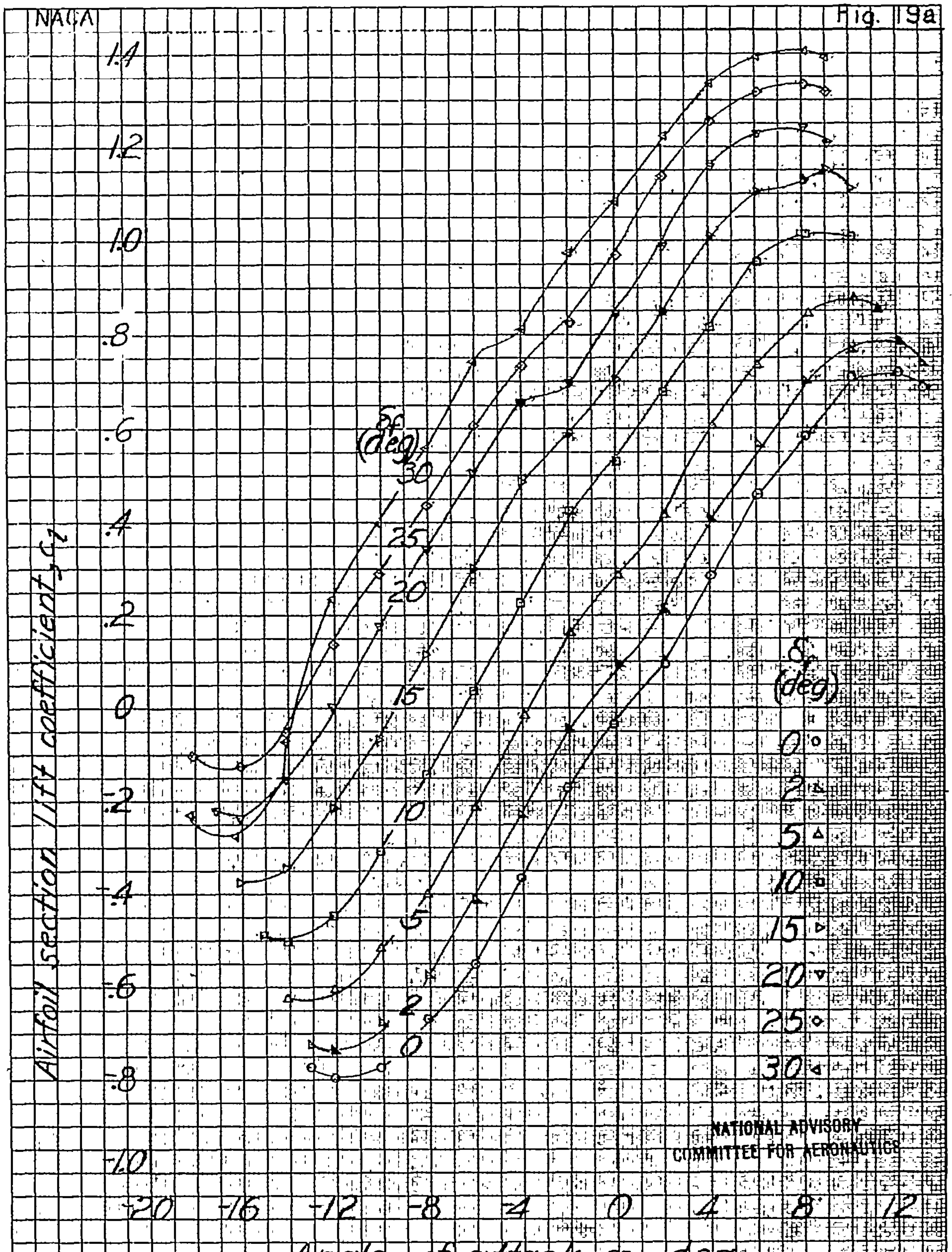
Figure 18.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. c_b/c_f = 0.50; $d\delta_b/d\delta_f$ = 1.00; 0.005c gap.

L - 350



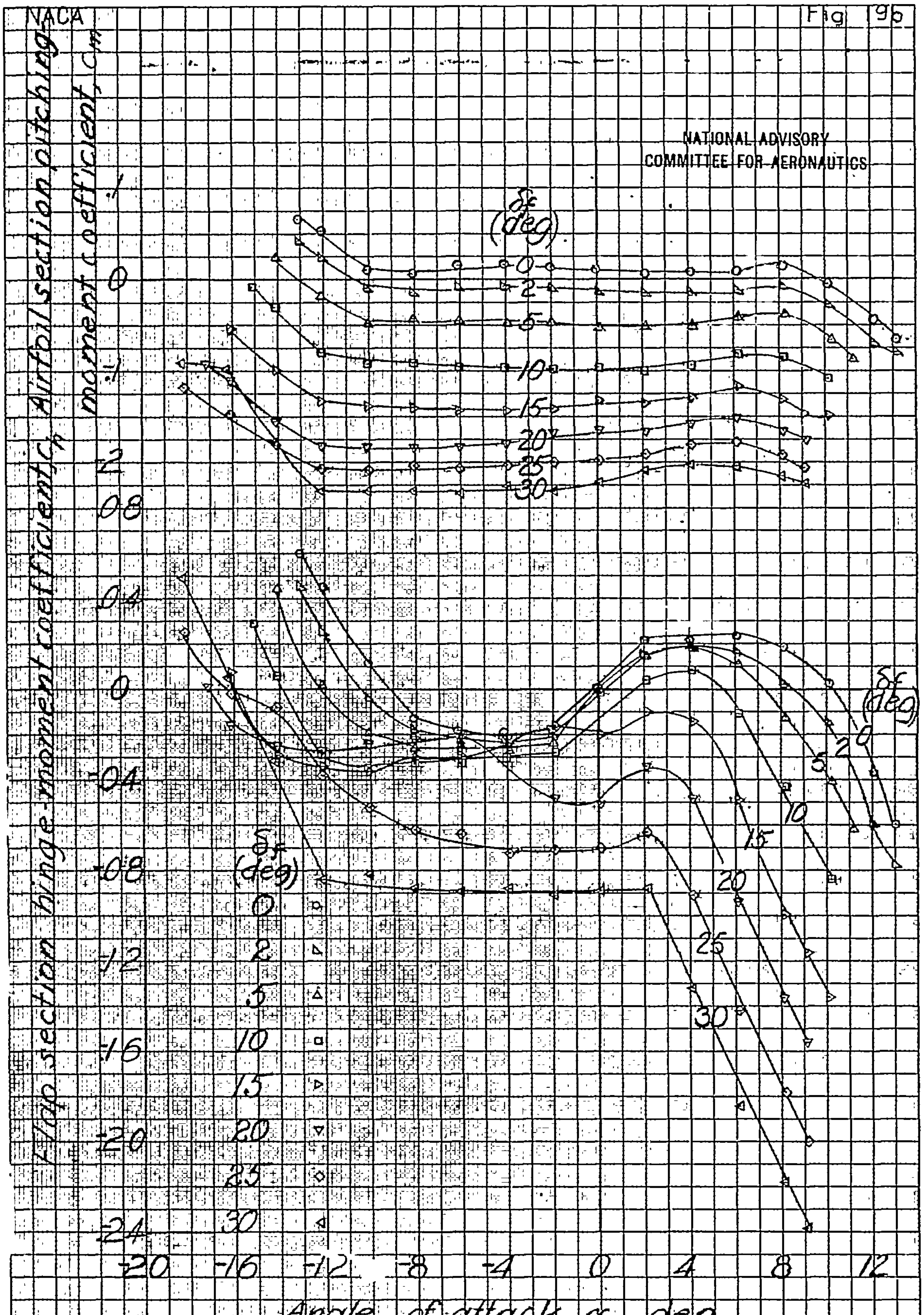
(b)

Figure 18.- Concluded.



(a)

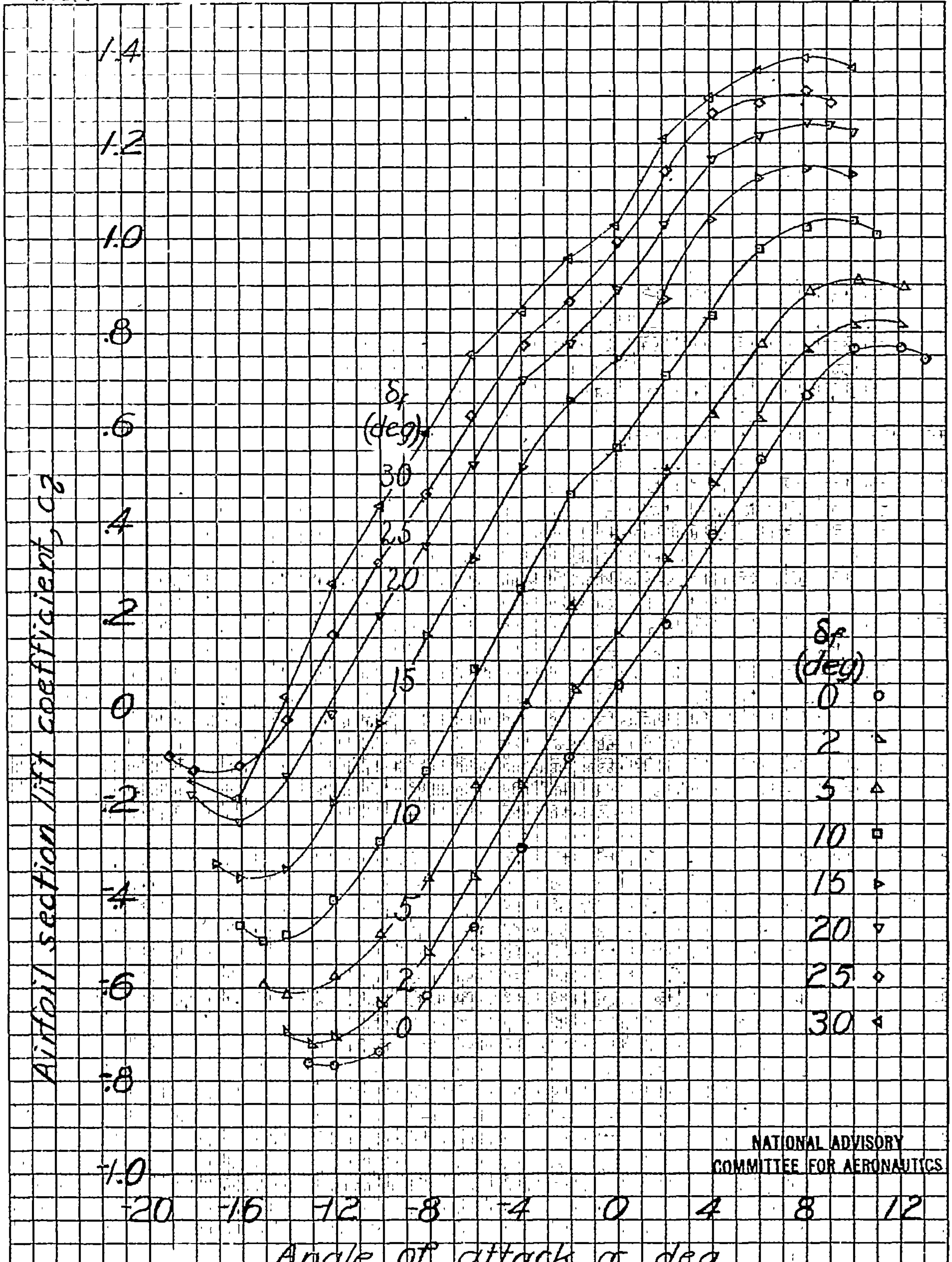
Figure 19-Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance c_b/c_f=0.75; d_b/d_f=0.39, 0.005c gap.



(b)

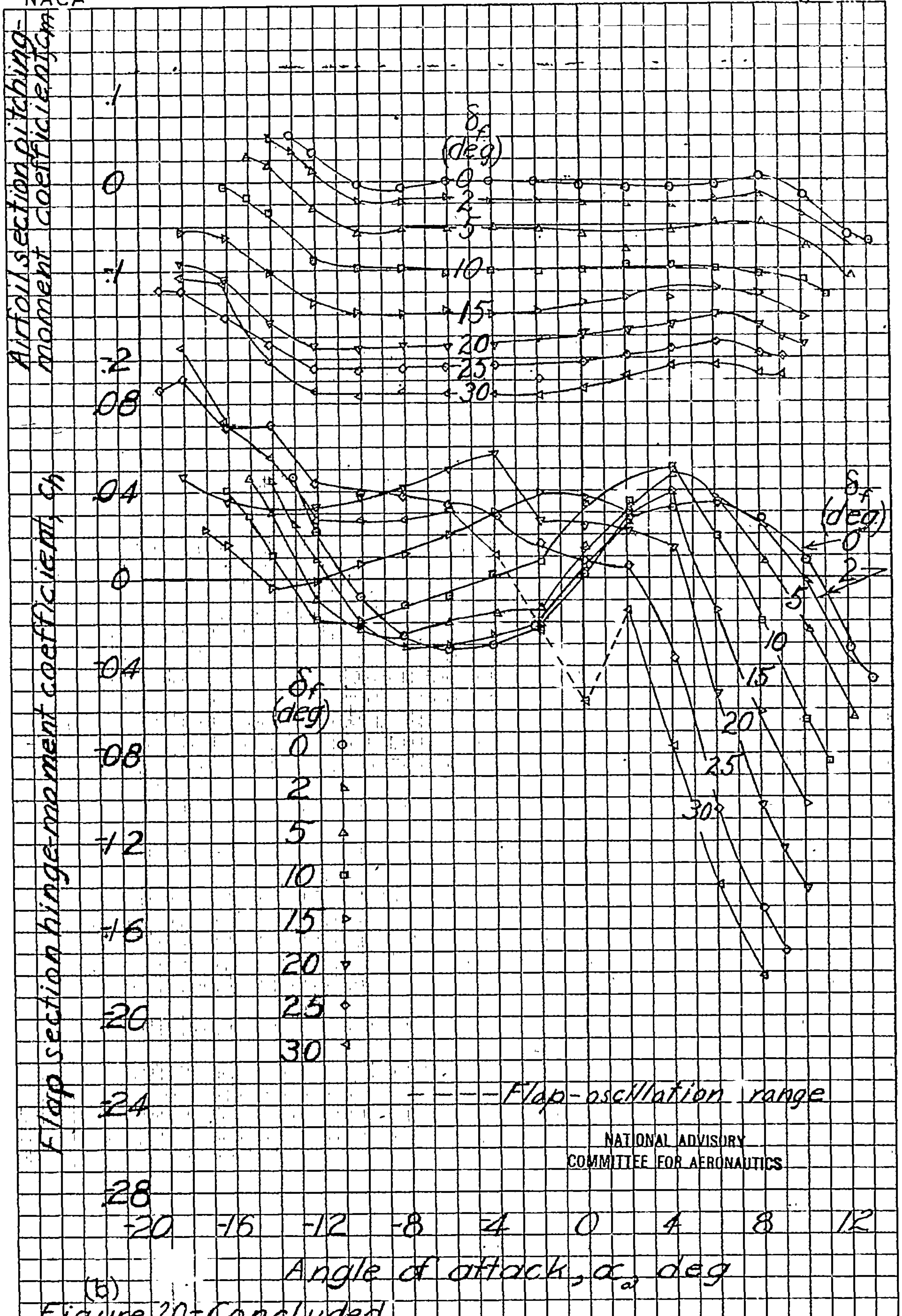
Figure 19- Concluded.

L-350



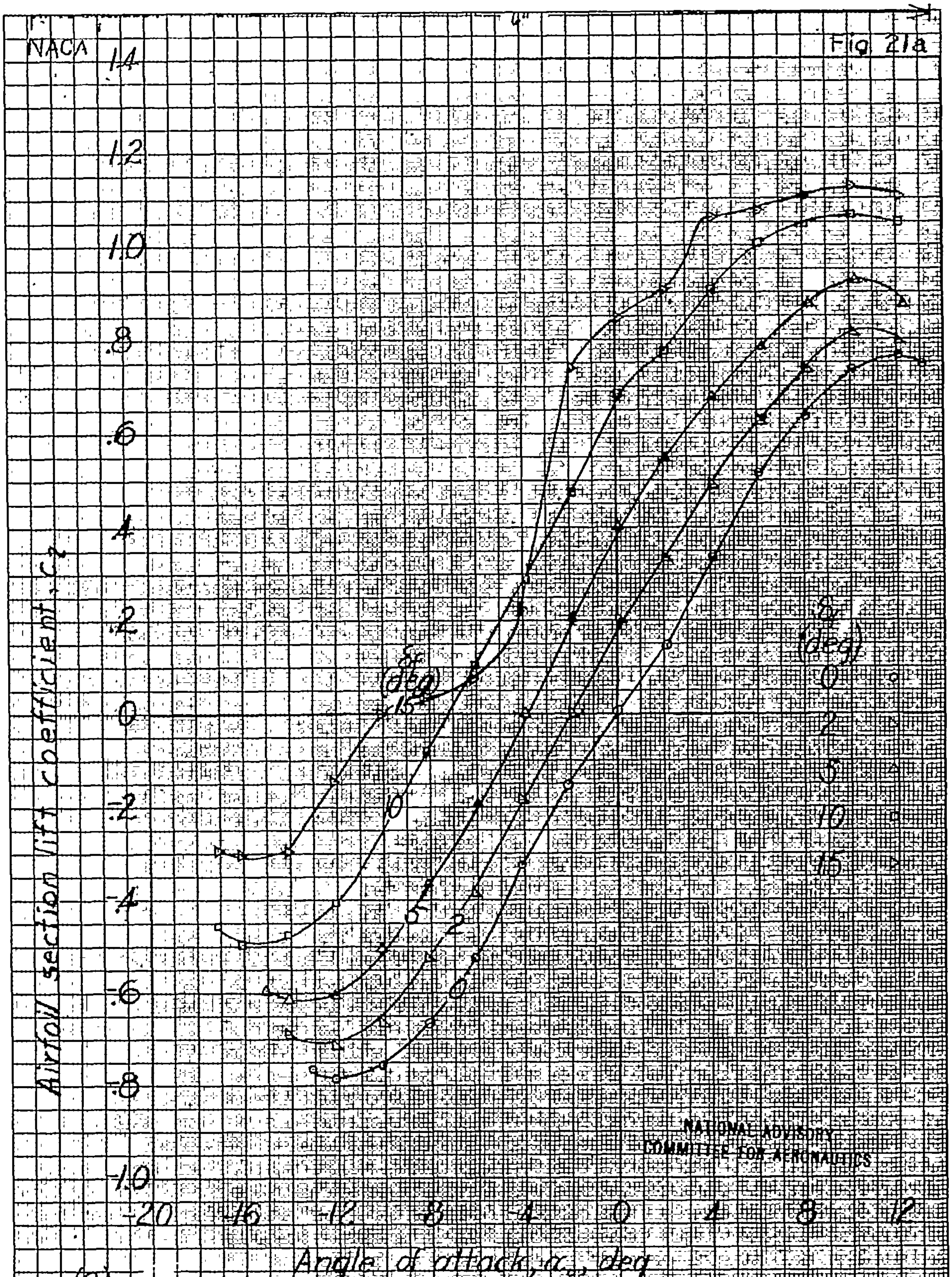
(a)

Figure 20.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. c_b/c_f = 0.73; d_b/c_f = 0.50; 0.0005c gap.



(b)

Figure 20- Concluded.



(a)

Figure 21.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. $c_{b/c_f} = 0.15$; $d\delta_t/d\delta_f = 1.00$; 0.005c gap.

NACA

I - 350

Fig. 21b

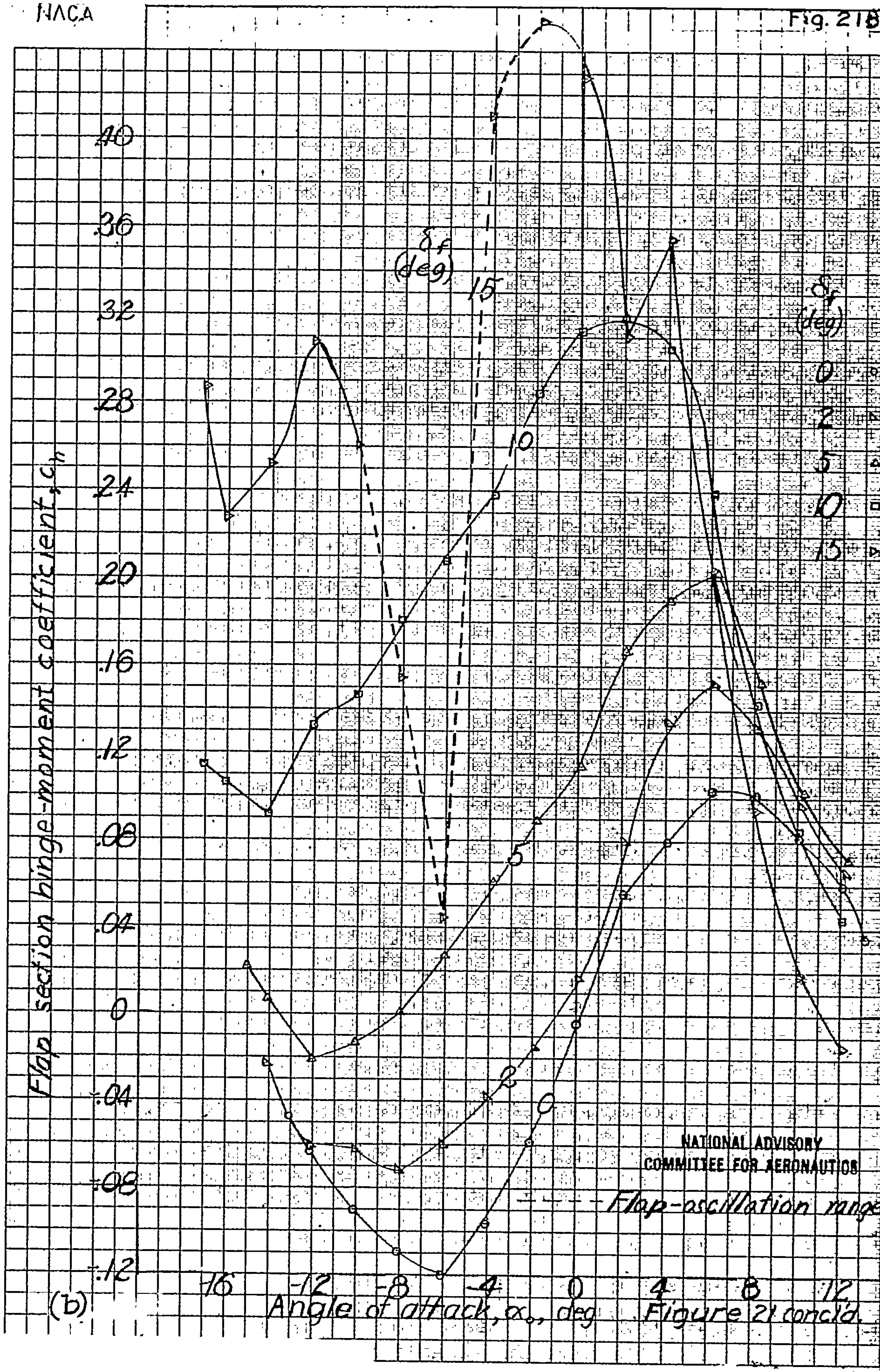
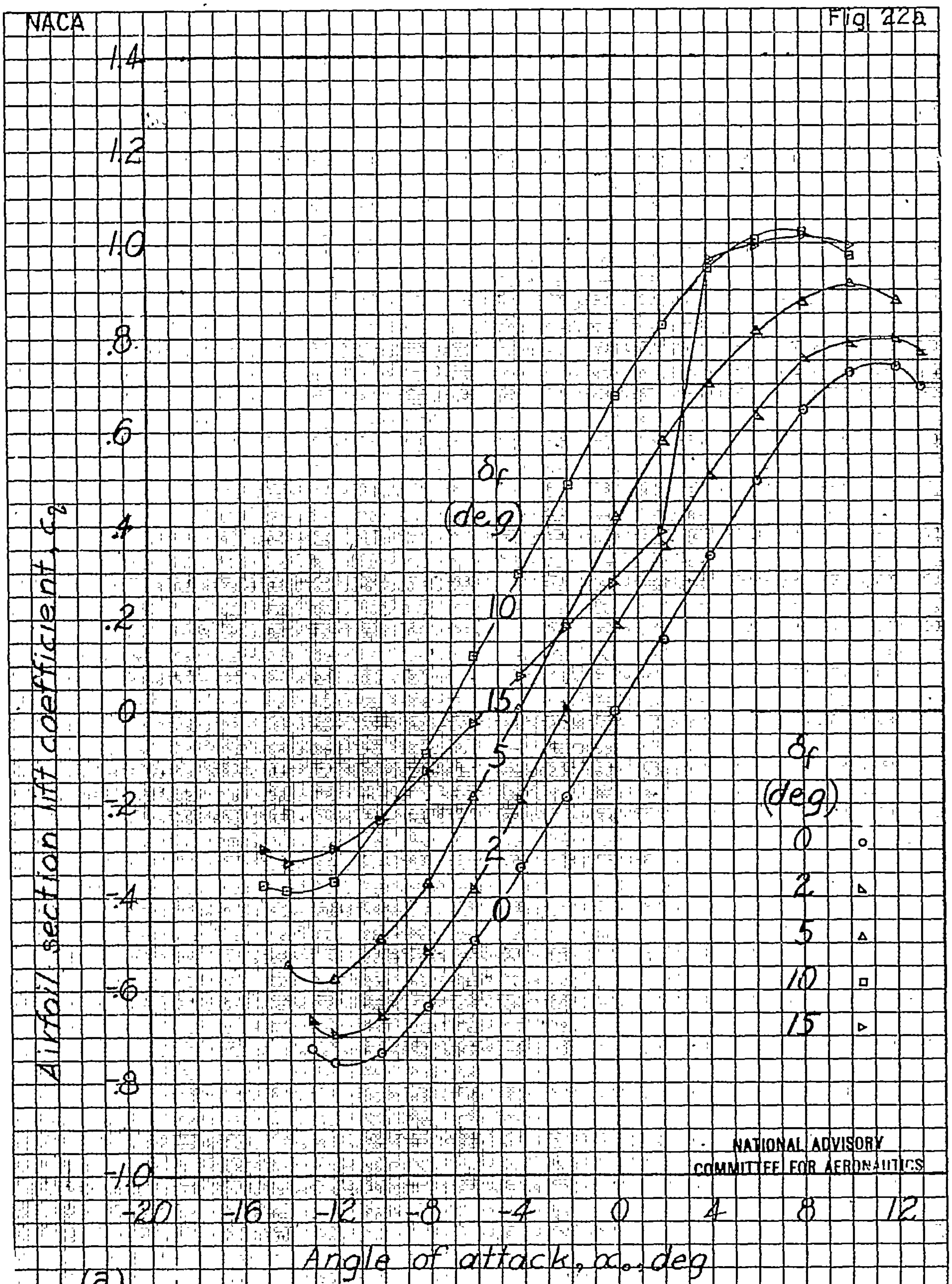


Figure 21 concld.

L - 350

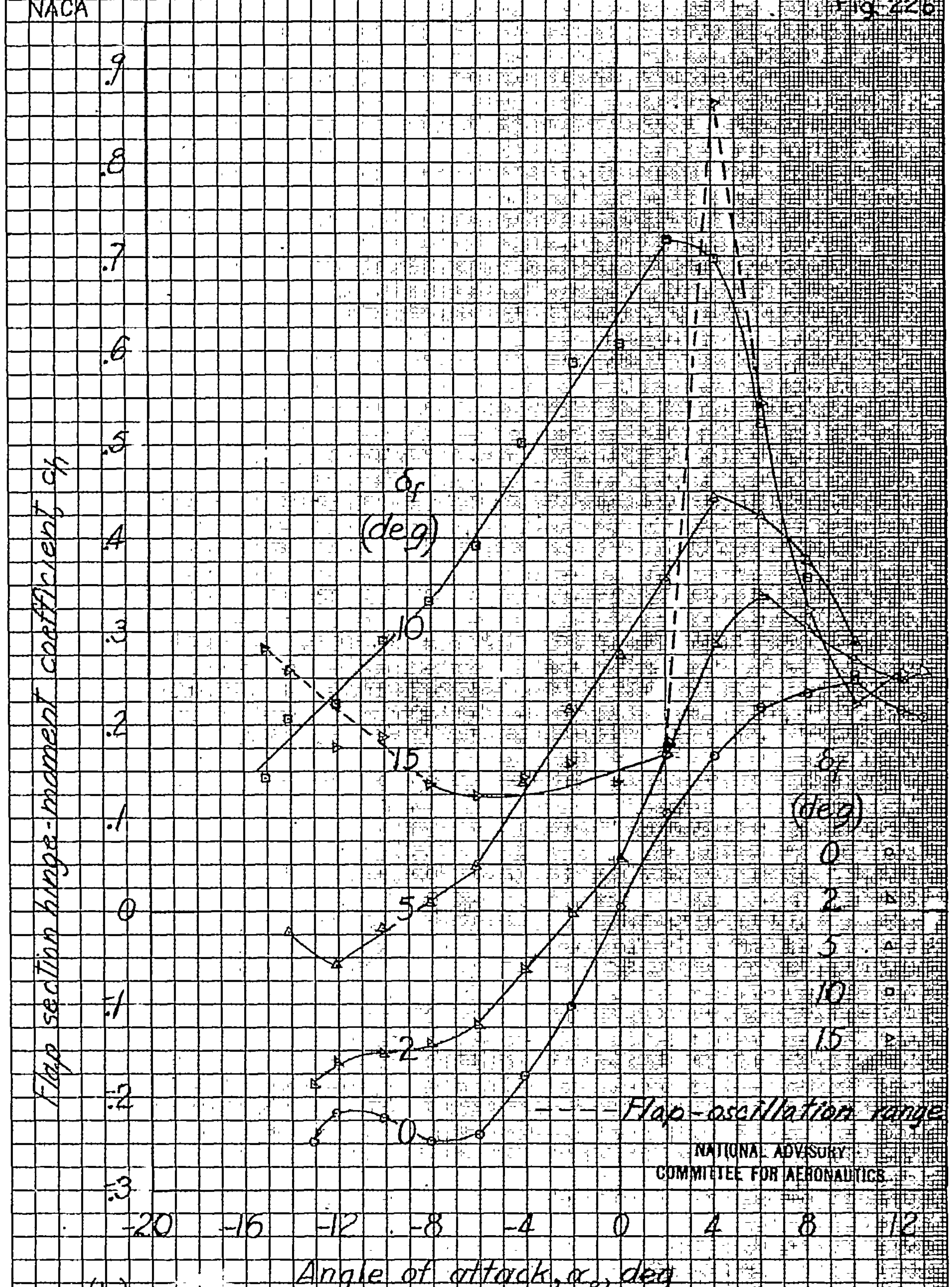


(a)

Figure 22.- Section aerodynamic characteristics of an NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. $c_b/c_f = 1.00$; $\delta_b/\delta_f = 1.00$; 0.005c gap.

L - 350

NACA Fig. 22b



(b)
Figure 22- Concluded.

L - 350

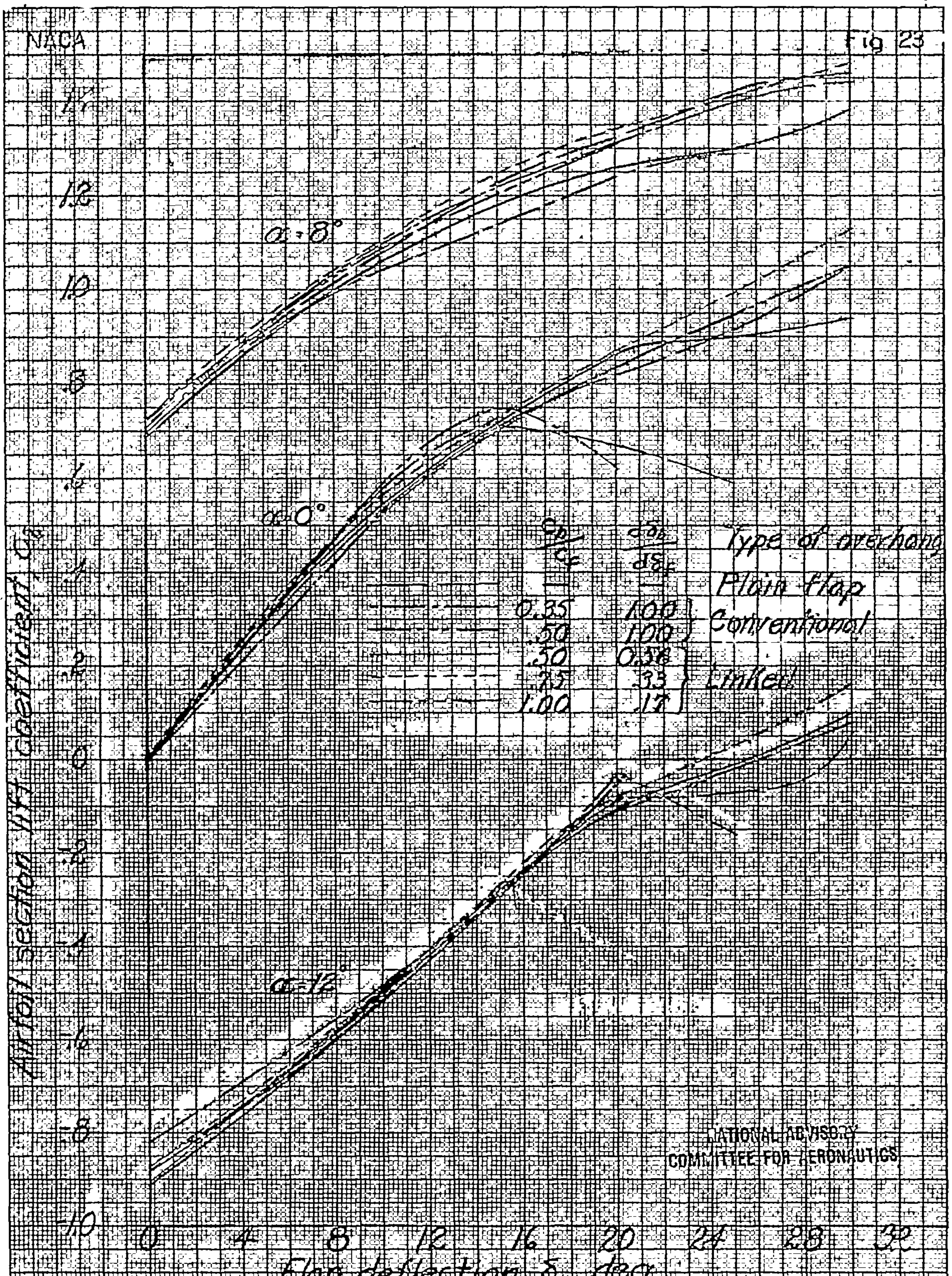


Figure 23.- Airfoil section lift coefficient as a function of flap deflection for various balance lengths and deflection rates on an NACA 66-009 airfoil with a 0.30c flap. Sealed gap.

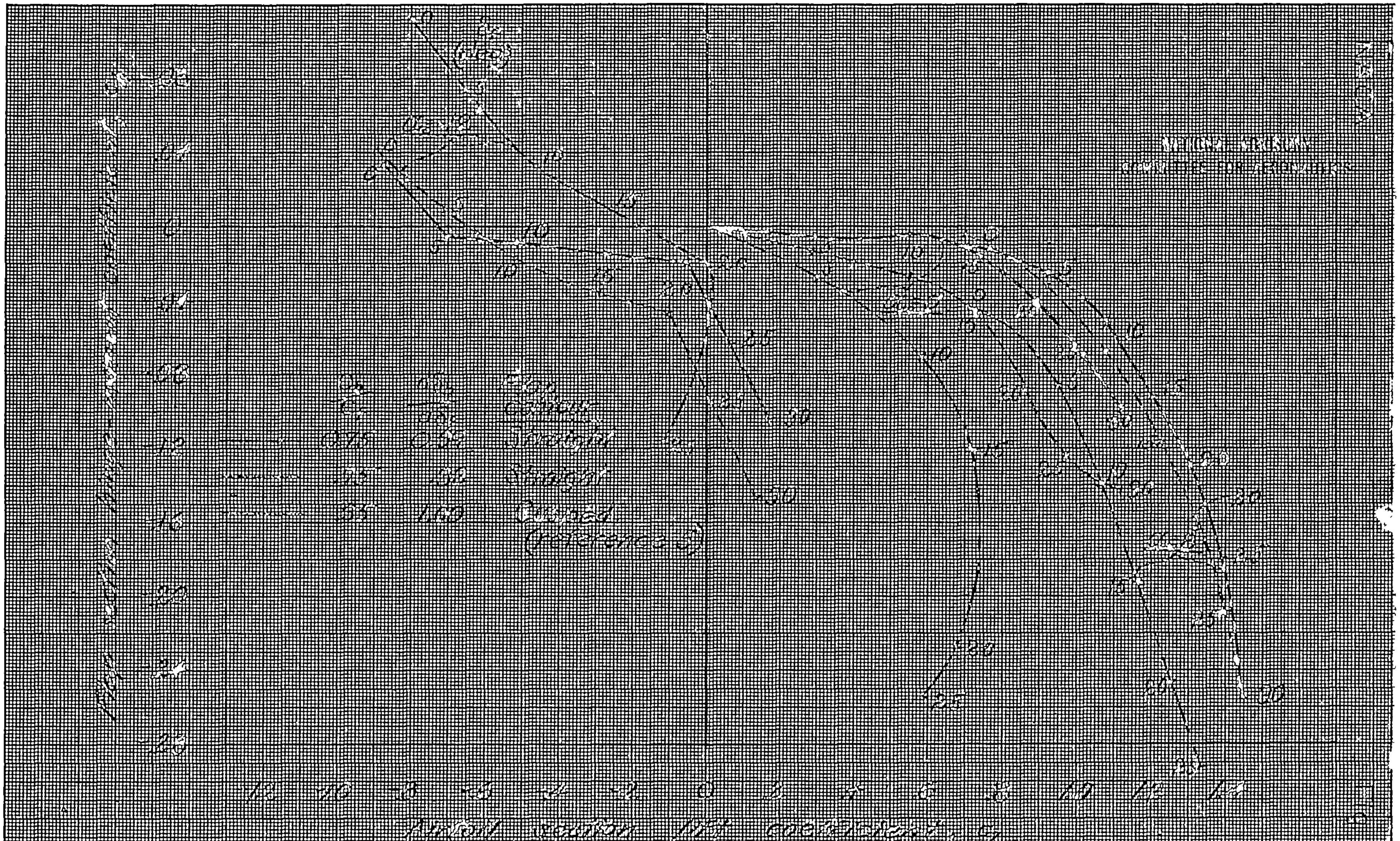


Figure 24.- Airfoil section lift coefficient as a function of flap section hinge-moment coefficient for various balance deflection ratios. [illegible] NACA [illegible] airfoil with a 0.30c flap.

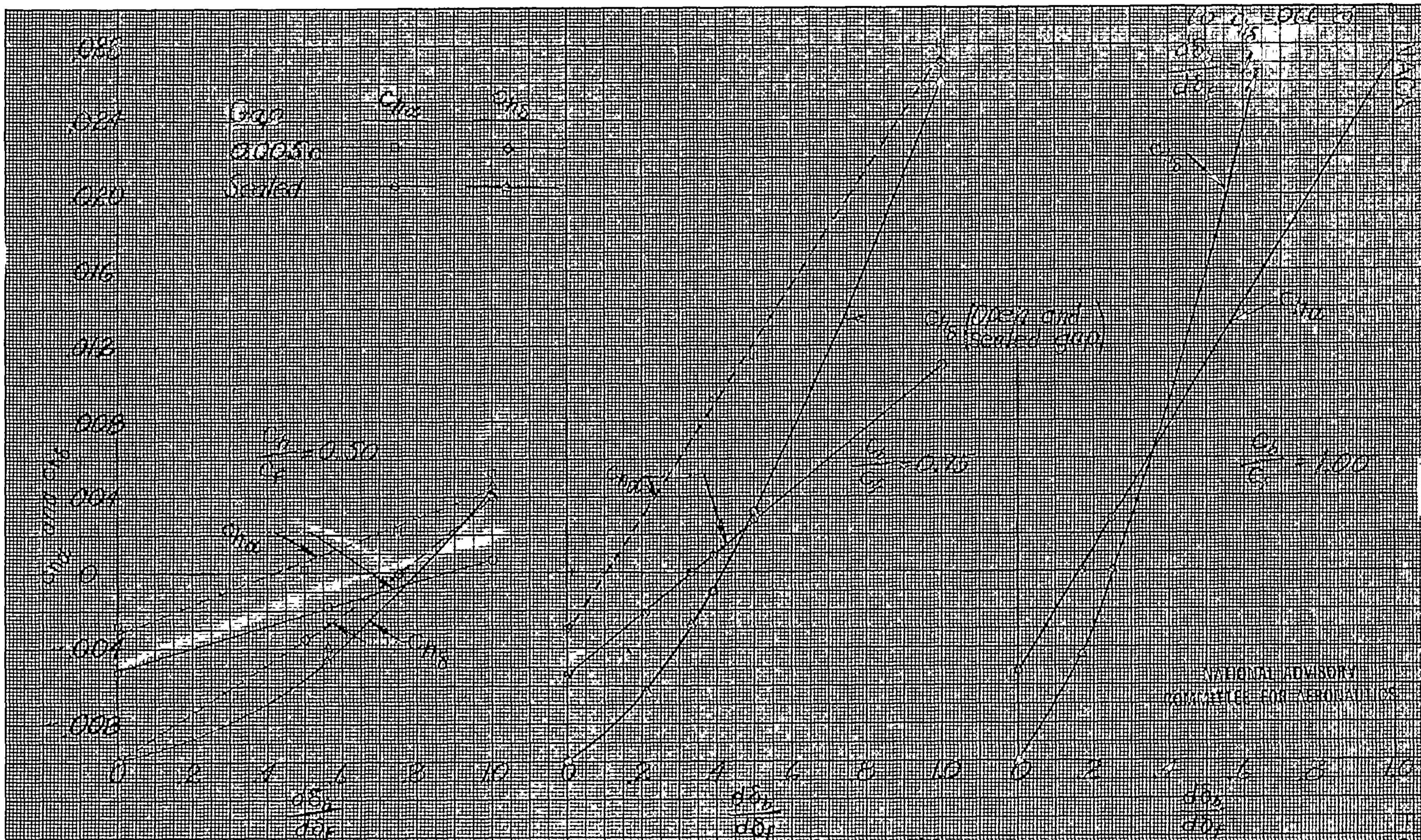


Figure 25.- Variation of parameters c_{h_α} and c_{h_δ} with rate of balance deflection for various balance lengths. NACA 66-009 airfoil with a 0.30c straight-contour flap having a linked balance. α_0, δ_f = 0°.

NACA Fig. 26

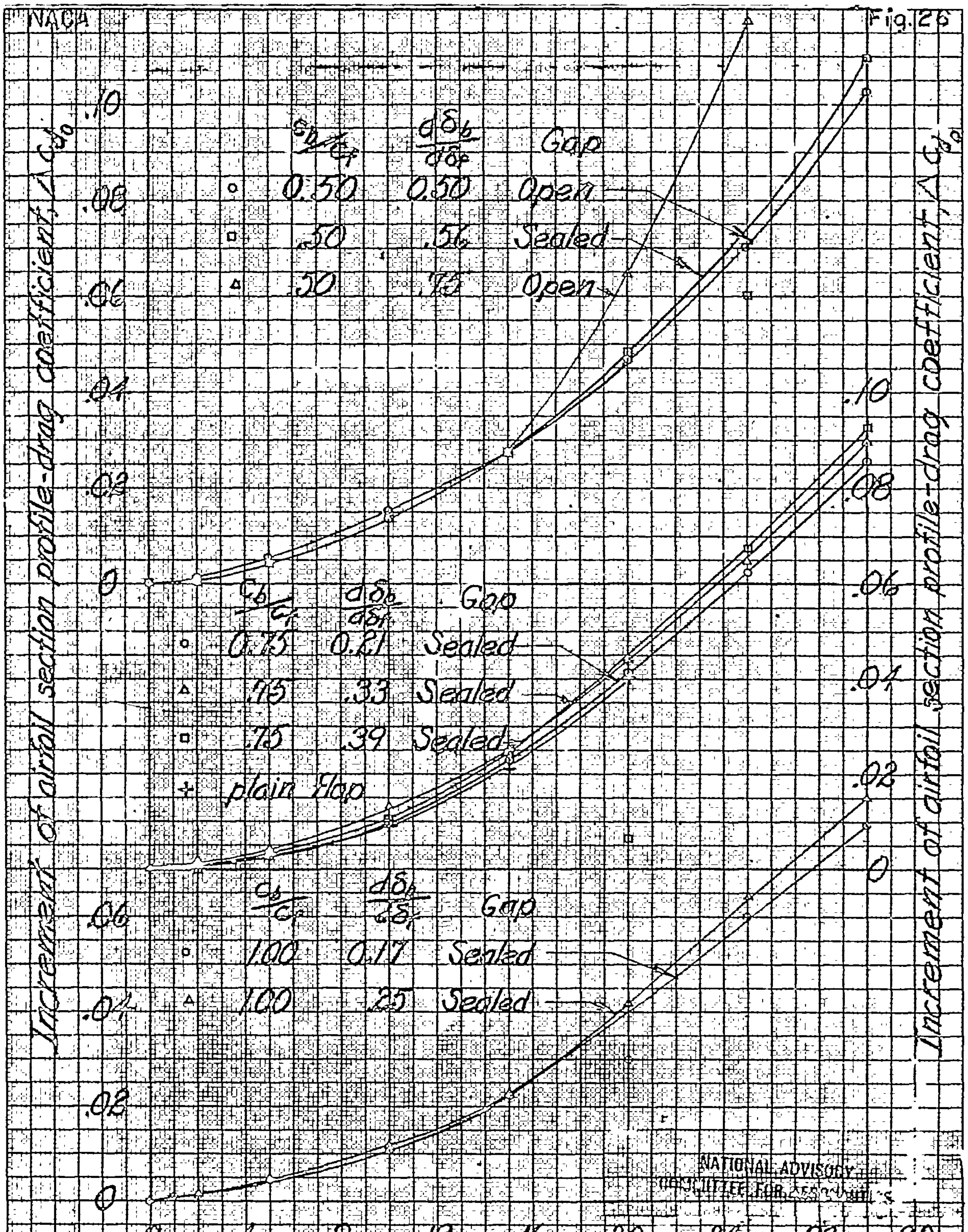


Figure 26.- Increment of airfoil section profile-drag coefficient caused by flap deflection. NACA 66-009 airfoil with a 0.30c straight-contour flap. $\alpha_0 = 0°$.